

/THE EFFECTS OF IRRIGATION ON THE CHEMICAL PROPERTIES
OF SOME NORTH CENTRAL AND SOUTHWESTERN KANSAS SOILS/

by

ROBERT MORTON DIXON

B. S., Kansas State University
of Agriculture and Applied Science, 1959

A THESIS

submitted in partial fulfillment of the

requirements for the degree

MASTER OF SCIENCE

Department of Agronomy

KANSAS STATE UNIVERSITY
OF AGRICULTURE AND APPLIED SCIENCE

1960

KANSAS STATE UNIVERSITY LIBRARIES

LD
2668
T4
1960
D62
c 2

TABLE OF CONTENTS

INTRODUCTION.	1
REVIEW OF LITERATURE.	1
Soluble Salt Accumulation	2
Exchangeable Sodium Accumulation.	3
Calcium Carbonate Accumulation.	5
DESCRIPTION OF SOIL SAMPLING SITES.	6
METHODS EMPLOYED.	10
Soil Sampling, Drying and Sieving	10
Irrigation Water Sampling	11
Chemical Analyses	11
Water Soluble Cations	11
Water Soluble Anions.	13
Ammonium Acetate Extractable Cations.	13
Cation Exchange Capacity.	14
Calcium Carbonate and Gypsum Equivalents.	14
Other Determinations.	15
Calculations.	15
RESULTS AND DISCUSSION.	17
General Considerations.	17
Sites in Mitchell and Osborne Counties.	18
Sites 1, 2 and 3; Soil - 1M4X	18
Site 4; Soil - 1M34D.	23
Site 5; Soil - 1M1X	25

10-24-60-810

Finney, Grant and Kearny Counties	
Sites 6, 7 and 8; Soil Series - "Richfield"	27
Salinity and Sodium Status of Waters.	27
Salinity, Alkali and Calcium Carbonate Status of Soils	28
Relations between Soils and Waters.	31
Haskell County; Sites 9, 10 and 11	
Soil Series - "Spearville".	32
Salinity and Sodium Status of Waters.	32
Salinity, Alkali and Calcium Carbonate Status of Soils	33
Relations between Soils and Waters.	35
Sites in Hamilton County.	36
Site 12; Soil Series - "Syracuse"	36
Site 13; Soil Series - "Las Animas"	39
Stevens County; Site 14	
Soil Series - Ulysses	41
Salinity and Sodium Status of Waters.	41
Salinity, Alkali and Calcium Carbonate Status of Soils	41
Relations between Soils and Waters.	42
Correlation and Regression Studies.	43
Relation between Soil and Water Characteristics .	43
Relation between SAR of Saturation Extract and ESP	45
SUMMARY	49
ACKNOWLEDGMENTS	53
LITERATURE CITED.	54

APPENDIX.	56
IRRIGATION WATER ANALYSES	57
SOIL ANALYSES	59
SOIL PROFILE DESCRIPTIONS	88

INTRODUCTION

Mineral salts tend to accumulate in river and ground waters between the time the water falls as precipitation and the time it is intercepted for irrigation. These dissolved salts affect the chemical properties of soils in a number of ways. Those effects which are of major concern to man are increases in soluble salts, exchangeable sodium, calcium carbonate and various toxic ions in the soils to which these waters are added. Soil problems may develop when the concentration of these substances reaches a critical magnitude.

This study was undertaken to determine the effects of irrigation on the soils of two of the major irrigated sections of the state — North Central and Southwestern Kansas. Primary emphasis of this study was centered on the effect of known quantities and relative composition of mineral salts in the irrigation waters as related to changes in the alkali, soluble salt, and calcium carbonate status of the soil. The toxic ion effects of irrigation waters were beyond the scope of this study.

REVIEW OF LITERATURE

Many of the past investigations in this area have been concerned primarily with the effects of irrigation as related to the accumulation of soluble salts, exchangeable sodium, and calcium carbonate in the soil. Consequently, the previous studies may be conveniently reviewed under these headings.

Soluble Salt Accumulation

Past findings indicate that a rise in the salinity status of a soil may result from the use of high salinity waters, from the irrigation of soils with restricted internal drainage, from insufficient application of irrigation waters or from any combination of these factors (2, 13, 14, 15). The more soluble salts such as CaCl_2 , MgSO_4 , MgCl_2 and all of the salts of sodium contribute the most to soil salinity since the less soluble salts, lime and gypsum, precipitate out of solution provided the soil dries and the soil solution becomes sufficiently concentrated. Doreen and Henderson (2) use the term "effective salinity" to denote the percentage of the total salts present in irrigation water which are of relatively high solubility. For instance, they reported that the effective salinity of the irrigation water in Lake County, California was only 27 per cent; i.e., 73 per cent of the total salts in the irrigation water would be expected to precipitate as the soil dries.

A study by Thorne and Thorne (14) has shown that the salt concentration of the soil solution of a well drained soil is closely related to the average salt content of irrigation waters. Other investigators (9, 10, 15) have drawn similar conclusions. Because of this close relationship between the salt status of irrigation waters and soil solution, the salt content of irrigation waters is considered a good measure of the salinity hazard associated with the use of the waters for irrigation (15). An irrigation water - soil solution equilibrium, however, assumes unrestricted internal drainage. The work of Harper and Stout (6) indicated that fine textured soil horizons may restrict internal drainage of irrigated soils with a resultant salt accumulation. Consequently, the salinity hazard of a water

is not only dependent upon the total soluble salt content but also upon the internal drainage conditions of the soil (15).

Electrical conductance is considered a quick and accurate measure of the salt content of irrigation waters and of soil saturation extracts (15). Per cent by weight also has been used to express the total salt content; however, electrical conductivity has been shown to be more closely correlated with the deleterious effects of high osmotic pressures (15) since both electrical conductivity and osmotic pressure are dependent upon the number of particles in solution. Soils are termed saline when the electrical conductivity of the saturation extract is equal to or exceeds 4 millimhos per cm. At salt concentrations of this level the growth and yield of many plants is restricted since under normal field conditions the soil solution is several times as concentrated as the saturation extract (15).

Exchangeable Sodium Accumulation

A number of investigations have shown that the exchangeable sodium percentage increases with the use of waters high in sodium content (8, 12, 14, 15). In laboratory experiments Kelly et al. (8) have demonstrated that, because of the exchange equilibrium, sodium adsorption increases with the Na: Ca + Mg ratio of the water with which the soil is shaken. Also, Lewis and Juve (9) in an Idaho study showed that the saturation extracts from well drained soils approach the cationic composition of the irrigation waters used. These equilibrium conditions have made feasible the prediction of the exchangeable sodium percentage of a well drained soil from the chemical analysis of the water (15).

In the classification of irrigation water the alkali hazard is ordinarily expressed as a function of the sodium percentage or the sodium adsorption ratio (SAR). The U. S. Salinity Laboratory staff (15) favor the use of SAR since it has been shown to be highly correlated with the exchangeable sodium percentage of the soil. Thorne and Thorne (14), however, have observed no definite advantage of the use of SAR over sodium percentage.

Recent work in West Texas (10) has shown a highly significant correlation between the SAR of the saturation extract and exchangeable sodium percentage but not between the SAR of the irrigation water and the exchangeable sodium percentage. Other workers also have noted lower correlations between the SAR of the irrigation water and the exchangeable sodium percentage than between the SAR of the saturation extract and exchangeable sodium percentage (15). This obviously points to marked and inconsistent changes in the SAR of irrigation waters as the irrigation water changes into the soil solution. From the equation defining SAR it is apparent that either the concentration of the soil solution as the soil dries or the precipitation of calcium and magnesium salts will serve to increase the SAR value of the soil solution over that of the irrigation water. In contrast, either the dilution of the soil solution by rainfall or the dissolving of additional calcium and magnesium salts from calcareous or gypsiferous soils (1) will serve to decrease the SAR of the soil solution.

A number of studies (3, 4, 5, 15) have shown that high concentrations of carbonate and bicarbonate ions in irrigation waters favor the precipitation of calcium and magnesium due to the common ion effect. This increases the relative sodium content and, consequently, the SAR of the soil

solution. To take into account the influence of carbonate and bicarbonate on the sodium content Eaton (3) suggested that sodium per cent possible (SPP) could be determined by the equation:

$$SPP = \frac{Na^+ \times 100}{(Ca^{++} + Mg^{++} + Na^+) - (CO_3^{--} + HCO_3^-)}$$

where concentrations are expressed in milliequivalents per liter (meq./l.) and the value taken for $(CO_3^{--} + HCO_3^-)$ does not exceed the $(Ca + Mg)$ value. The hazard associated with using irrigation waters of high carbonate and bicarbonate content was defined by Eaton (3) as the residual sodium carbonate (RSC) and is found by the equation:

$$RSC = (CO_3^{--} + HCO_3^-) - (Ca^{++} + Mg^{++})$$

where concentrations are expressed in meq./l. Studies conducted at the U. S. Salinity Laboratory (15) have indicated that waters containing more than 2.5 meq./l. of residual sodium carbonate are unsuitable for irrigation unless amendments are employed to precipitate some of the carbonate.

Soils are termed alkali when the exchangeable sodium percentage is equal to or greater than 15 and the electrical conductivity in millimhos per cm. is less than 4. Physical structure of the soil is often affected adversely when the exchangeable sodium percentage is of this magnitude unless sufficient soluble salts are present in the soil solution to keep the zeta potential of the soil colloids repressed below the critical point.

Calcium Carbonate Accumulation

Past investigations have shown that calcium carbonate may accumulate in soils irrigated for long periods of time with waters high in calcium,

carbonate and bicarbonate ions (5, 16, 17). High concentrations of these ions favors the precipitation of calcium carbonate when the irrigation water becomes the soil solution and is concentrated several fold. It might be assumed that the solubility product constant (K_{sp}) could be employed to predict calcium carbonate accumulation. The solubility product constant, however, is confounded by the fact that the solubility of calcium carbonate increases with the soluble salt content of the soil solution and with the partial pressure of CO_2 .

Chlorosis in susceptible plants has been attributed to a high calcium activity in the soil (11). Chlorosis is most generally considered to result from a tie-up of iron by calcium.

DESCRIPTION OF SOIL SAMPLING SITES

With the cooperation of personnel of the U. S. Department of Agriculture Soil Conservation Service, 14 soil sites were selected as representative of large acreages under irrigation. At each site an irrigated and a non-irrigated soil of the same soil type were sampled for comparison. Five of these comparison sites were located in Mitchell and Osborne Counties, 3 in Finney and Grant Counties, 3 in Haskell County, 2 in Hamilton County and 1 in Stevens County. The identification numbers and general locations of these sites are given in Figures 1 and 2.

The sites, designated 1, 2 and 3 (mapping symbol 1MAX) in Figure 1 and elsewhere in this thesis, were chosen to be representative of the Solomon River Valley soils in Mitchell and Osborne Counties. These soils generally have 12 to 14 inches of silt loam to silty clay loam topsoil and several feet of silt loam to clay loam subsoil. The soil is underlaid with recent alluvium. Permeability of the subsoil and substratum is moderate.

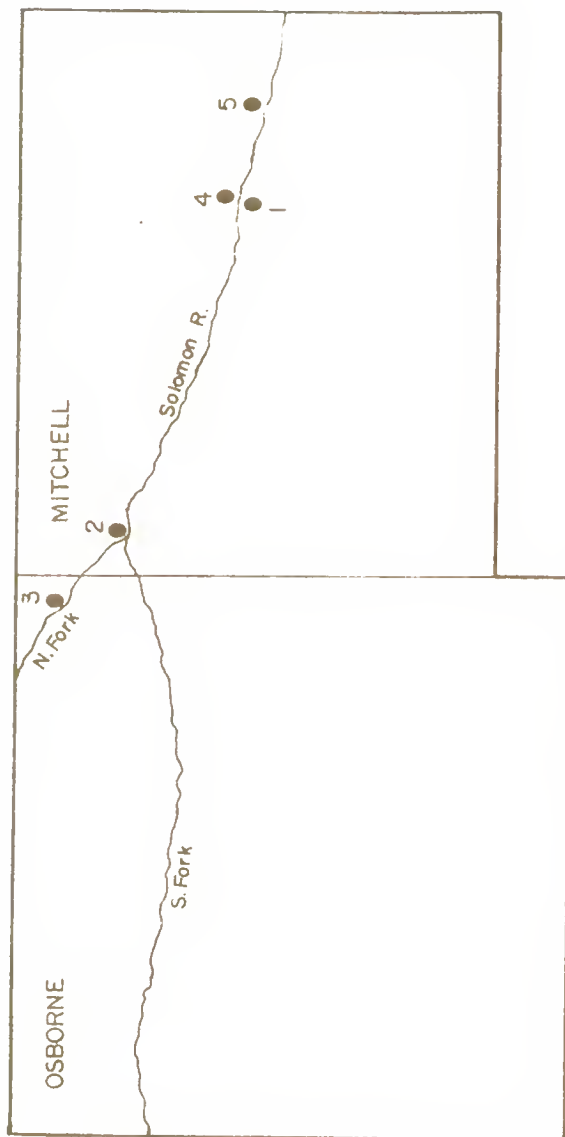


Figure 1. General location of soil sampling sites in North Central Kansas.

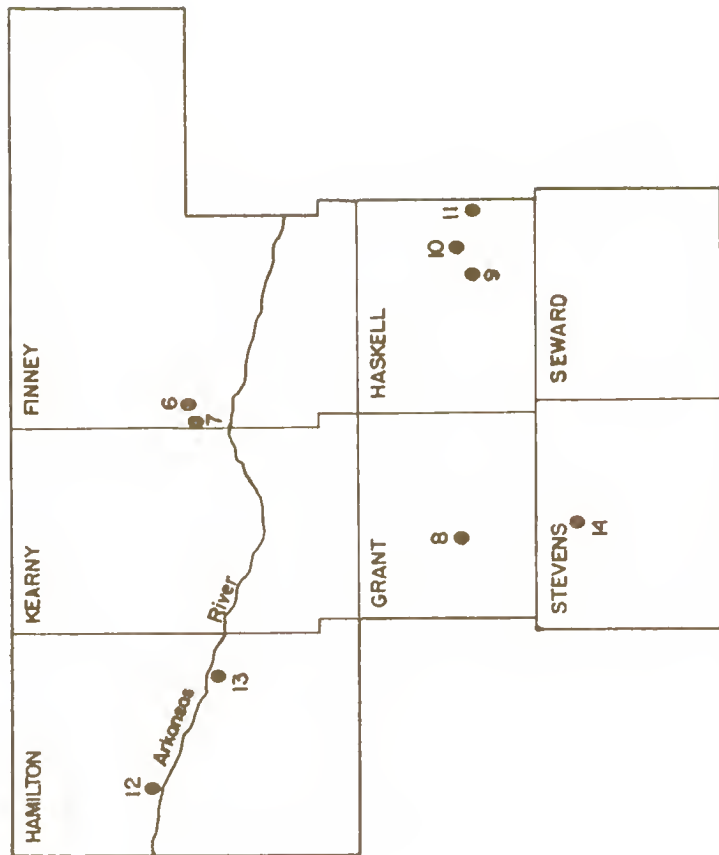


Figure 2. General location of soil sampling sites in Southwestern Kansas.

Site 4 (mapping symbol LM34D) was selected to represent the soils which generally occur adjacent to the bottomlands of the Solomon River in Mitchell County. These soils are characterized by 10 to 14 inches of friable silty clay loam topsoil and 16 to 24 inches of silty clay loam subsoil underlaid with loess. The permeability of the subsoil is moderately slow and that of the substratum is moderate.

Site 5 (mapping symbol LM1X) was chosen to represent the slowly permeable, fine textured soils which occur along Carr Creek in the western part of Mitchell County, along Salt Creek in the southern part, and some of the broad terraces along the Solomon in the central part of the county. These soils are characterized by a fine textured topsoil and subsoil underlaid with recent alluvium. Surface and subsurface drainage tend to be slow or restricted.

Sites 6, 7 and 8 of Finney and Grant Counties were located in soils of the "Richfield" series. In Finney County these soils occur chiefly north of the Arkansas River Valley and in Grant County they occupy the almost level uplands. These soils usually have from 5 to 8 inches of medium to fine textured topsoil and a medium textured subsoil. Soft lime concretions often are encountered at depths of 18 to 30 inches. These soils are derived largely from loess.

Comparison sites 9, 10, and 11 in Haskell County have the tentative classification "Spearville silty clay loam." The soils of this type generally have 4 to 8 inches of silty clay loam topsoil and 14 to 20 inches of light silty clay to silty clay subsoil. Lime concretions are often found at 15 to 30-inch depths. These soils were formed from loess and occur over much of the broad flat upland of the county.

Sites 12 and 13 were located along the bench or terrace lands adjacent to the Arkansas River in Hamilton County. The soil of site 12 has tentatively been classified as "Syracuse clay loam" and the soil of site 13 as a "Las Animas clay loam." These soil series are quite similar except that in some areas the "Las Animas" series has a high alkali status. Both series are characterized by a grayish brown, light clay loam to clay loam surface soil and a sandy clay loam to clay loam subsoil and substratum. Internal drainage is excellent and in some places coarse sands and gravels are found at 5 to 6-foot depths.

Site 14, was located in extreme North Central Stevens County and the soil was classified as Ulysses clay loam. These soils are deep medium textured soils formed from loess. Lime concretions often occur at 20 to 40-inch depths.

METHODS EMPLOYED

Soil Sampling, Drying and Sieving

Fourteen soil sampling sites were selected (Fig. 1 and 2) to be representative of large acreages under irrigation in North Central and Southwestern Kansas. An irrigated and a non-irrigated or short-time irrigated profile were sampled by horizons to approximately 5-foot depths at each site. Soil samples were obtained with a truck-mounted 2-inch hydraulic probe and were placed in one-quart ice cream cartons for transportation back to Manhattan and for storage.

The samples were air dried in a greenhouse by spreading on sheets of brown wrapping paper and allowing to stand for several days. Prior to

analysis the soils were passed through a 2-mm. sieve. The large coherent clods were ground with a Crescent hand grinder.

Irrigation Water Sampling

Well-water samples were taken in quart polyethylene bottles or glass Mason jars at the time the soils were sampled in August 1958 whenever possible. Samples that could not be obtained at this time were obtained 1 to 2 months later and mailed to Manhattan. Chemical analyses for the past several years of the Solomon River at Downs and Beloit and the Arkansas River at Dodge City were furnished by the Kansas State Department of Health.

Chemical Analyses

The chemical determinations made on each irrigation water and soil sample were as follows: pH of irrigation water, saturated paste, and saturation extract; electrical conductivity of irrigation water and saturation extract; water soluble cations and anions in irrigation water and saturation extract; ammonium acetate extractable cations of soil; cation exchange capacity of soil; and the gypsum and calcium carbonate equivalent of the soil.

Water Soluble Cations. Soluble cations (K^+ , Na^+ , Ca^{++} and Mg^{++}) of saturation extracts and irrigation waters were determined directly by the use of a Beckman, Model DU Spectrophotometer. Flame photometer conditions used are given in Table 1.

Table 1. Flame photometer conditions for determining water soluble and ammonium acetate extractable cations.

	Oxygen	Acetylene	Wave	Slit	Phototube	Photo-	Zero	Phototube
Cation:	pressure:	pressure:	length:	width:	load	multi-	suppres-	color
	(p.s.i.):	(p.s.i.):	(mm)	(mm)	resistor	plier	sion	sensitivity
K	10	4	772	.04	3	1	1	Red
Na	10	4	592	.02	2	1	1	Blue
Ca	10	4	556	.06	2	2	0 or 1	Blue
Mg	10	4	285.5	.06	2	4	0	Blue

The following ranges in concentration of standard solutions for the various cations were employed: potassium, 0-2 meq./l.; sodium, 0-4 meq./l.; calcium, 0-8 meq./l.; and magnesium, 0-4 meq./l. A set of from 30 to 40 samples were determined with the flame photometer at a time. Before determining a set of solutions, several standard solutions were checked against the appropriate standard curve and if changes in the operating conditions of the flame photometer were indicated the standard curve was redrawn. Dilutions of the test solutions were made whenever the per cent transmittance exceeded 100.

The saturated soil paste was prepared according to Method 2 of Agricultural Handbook No. 60 (15). Five hundred grams of soil were required to obtain sufficient extract for the analyses which were made. After mixing, the pastes were allowed to stand 12 hours in the covered stainless steel mixing cans in order to obtain equilibrium between the soil and the added water. The saturation extract was obtained by Method 3 of Agricultural Handbook No. 60 (15). A drop of toluene was added to each extract and to each irrigation water sample to inhibit bacterial growth prior to analysis.

Water Soluble Anions. The water soluble anions in the irrigation water and saturation extract were determined by methods given in Agricultural Handbook No. 60 (15). The carbonate and bicarbonate of the saturation extract and irrigation water were determined by acid titration according to Methods 12 and 82, respectively. A comparison color standard, adjusted to pH 3.7, was employed to obtain a reproducible methyl orange endpoint.

Chloride, in the saturation extract and irrigation water, was determined by titration with silver nitrate according to Methods 13 and 84, respectively. Method 14b was employed for the sulfate analysis. This method involves the precipitation of the sulfate ion as calcium sulfate which then is determined conductrimetrically. For the conductrimetric determinations, an Industrial Instruments Model RC-EC conductivity bridge was used. The electrical conductivity of the test solutions was adjusted to 25°C by the use of the correction factors of Table 15, p. 90 in Agricultural Handbook No. 60 (15).

Ammonium Acetate Extractable Cations. The cations were extracted by shaking 4 grams of soil with 100 ml. of neutral 1 N ammonium acetate together in a 150-ml. bottle. The mixture was shaken for 20 minutes on a reciprocating shaker and then was allowed to settle a few minutes before being filtered. Aliquots of the filtrates were analyzed directly by the flame photometer for extractable cations. Flame photometer conditions used are given in Table 1. The following ranges in standard solution concentrations for the various cations were employed: potassium, 0-1 meq./l.; sodium, 0-2 meq./l.; calcium, 0-8 meq./l.; magnesium, 0-4 meq./l.

Cation Exchange Capacity. With a few changes, Method 19 of Agricultural Handbook No. 60 (15) was used in the determination of the cation exchange capacity. The changes were as follows:

- (1) The combined ammonium acetate extracts were diluted to 200 ml. instead of 100 ml.
- (2) A top sodium standard of 8 meq./l. was employed in place of a 4 meq./l. standard to eliminate further dilutions.
- (3) Instead of shaking, the soil was resuspended after each centrifugation with a rubber ball mixer.

Method 19 involved saturation of the exchange complex with sodium, the removal of excess salts by washing with 95 per cent ethanol and the extraction of the adsorbed sodium with ammonium acetate. The sodium content of the combined extracts then was determined directly with the flame photometer. In washing the soil with ethanol, care had to be exercised to prevent the dispersion of soil colloids. Dispersion generally occurred when the electrical conductivity of the wash solution fell below 20 micromhos per cm.

Calcium Carbonate and Gypsum Equivalents. The alkaline-earth carbonates were determined by acid neutralization according to Method 23C of Agricultural Handbook No. 60 (15).

Gypsum determinations were made on soils containing greater than 15 meq./l. of soluble calcium. Gypsum is soluble to the extent of about 30 meq./l.; however, an excess of a common ion would depress the solubility somewhat. Methods 22a and 22b of Agricultural Handbook No. 60 (15) were followed except that the extract was separated by centrifugation rather than filtration. After shaking, the soil-water mixtures were poured into

100-ml. polyethylene centrifuge tubes and were centrifuged at 2000 r.p.m. for 10 minutes in a Model MA & ME International Centrifuge. Then a 20-ml. aliquot was pipetted directly from the supernatant liquid in the centrifuge tube into a 50-ml. conical centrifuge tube to be determined according to Method 22b.

Other Determinations. The pH of the saturation paste and saturation extract were determined by a Beckman pH meter.

An Industrial Instruments Model RC-EC conductivity bridge with a pipet type conductivity cell was employed in determining the electrical conductivity of the saturation extract. Resistance readings were corrected to the standard temperature of 25°C by the conversion factors of Table 15 in Agricultural Handbook No. 60 (15).

Calculations

All soil determinations were converted to an oven dry basis by making allowances for the air dry moisture content at the time the soil samples were weighed for analysis. For instance, 511.5 grams of air dry soil (500 grams, oven dry basis) were used for the saturation paste, 4.09 grams of air dry soil (4 grams, oven dry basis) were used for cation exchange capacity, etc.

The exchangeable cations K^+ , Na^+ , Ca^{++} , Mg^{++} were calculated and reported as the difference between the extractable and soluble quantities of the particular ion. In calcareous horizons, this manner of calculation yielded excessively high exchangeable Ca values and, in some cases, excessively high exchangeable Mg values due to the dissolution of calcium carbonate and dolomite by the extracting solution (?).

The exchangeable sodium percentage (ESP) was obtained by the equation

$$ESP = \frac{100 \times \text{Exchangeable Sodium}}{\text{Cation Exchange Capacity}}$$

where exchangeable sodium and cation exchange capacity are expressed as meq. per 100 grams of soil.

The sodium adsorption ratio (SAR) of the saturation extract and irrigation waters was calculated by the equation

$$SAR = \frac{Na}{\sqrt{\frac{Ca + Mg}{2}}}$$

in which Na, Ca, and Mg represent concentrations in meq./l. of the respective ions.

The profile means for the soluble cation totals, calcium carbonate equivalents, exchangeable sodium percentages and sodium adsorption ratios were weighted to take into account the depth of soil represented by the soil sample of each horizon.

Weighted means for the profiles of each comparison site were calculated to the shallowest sampling depth. For example, the profile sampling depths of site 1 were 48 and 66 inches; consequently, weighted means were determined to the 48-inch depth for both profiles.

In the calculation of saturation percentage (SP) the following equation was used;

$$SP = 100 \times \frac{\left(\begin{array}{l} \text{Weight of} \\ \text{saturated paste} \\ \text{and mixing can} \end{array} \right) - \left(\begin{array}{l} \text{Weight of} \\ \text{oven dry soil} \\ \text{and mixing can} \end{array} \right)}{\text{Weight of oven dry soil}}$$

The per cent sodium possible was calculated according to the defining equation as proposed by Eaton (3).

RESULTS AND DISCUSSION

General Considerations

In the ensuing discussion and report of results it was generally assumed that differences between the determined chemical status of the irrigated soil and non-irrigated control were differences arising largely from irrigation instead of from native profile dissimilarities or experimental error. It should be stressed, however, that where differences were small or unreasonably large the probability that irrigation was largely responsible diminishes somewhat.

Results of chemical analyses of irrigation waters and soils are included in the appendix in Tables 15 through 30. Also included in the appendix, pages 88 to 119, are profile descriptions furnished by Robert K. Glover and Rodney Warner, Soil Scientists of the U.S.D.A. Soil Conservation Service who described the soils and assisted in taking the samples and locating the sites.

In the discussion weighted means of soil determinations for the entire profile were employed to characterize the overall effects of irrigation. Changes in the total soluble salt content, water soluble sodium, exchangeable sodium and sodium adsorption ratios are reported in this manner. These weighted means, along with the corresponding average constituents in the irrigation waters, were arranged in tables and are presented on the following pages to aid in a three-way comparison of the characteristics of irrigated and non-irrigated soils and the water applied to these soils. To study the relationships between the chemical characteristics of corresponding saturation extracts and irrigation waters the following ratios

were employed: (1) TSC_e/TSC_{iw} , (2) SSP_e/SSP_{iw} , and (3) SAR_e/SAR_{iw} where TSC represents total soluble salt content, SSP represents soluble sodium percentage and SAR represents sodium adsorption ratio and the subscripts iw and e represent the source, i.e., irrigation water and saturation extract, respectively. Weighted means for the entire profile were used to represent the saturation extract determinations in the ratios, since the constituents in individual horizons of the same profile often varied considerably due to local conditions.

Past studies (15) have shown that the TSC_e/TSC_{iw} ratio ordinarily varies from 1 to 3 for well drained soils irrigated for long periods of time. In other words, the saturation extract is usually 1 to 3 times more concentrated than the corresponding irrigation waters.

Sites in Mitchell and Osborne Counties

Sites 1, 2 and 3; Soil - 1N4X. Soil sites 1, 2, and 3 were located on the Gerald Van Pelt farm and the A. F. Thille farm in Mitchell County and the Warren Carey farm in Osborne County.

Salinity and Sodium status of Waters. The irrigated soils of sites 1, 2 and 3 had been irrigated with Solomon River waters for 7, 6 and 12 years at the rates of 25, 20 and 7 inches per year, respectively, prior to the time the soils were sampled in August 1958.¹ At Beloit the river water contained 5.15 milliequivalents per liter (meq./l.) of salt of which 28.54 per cent was sodium. At Downs the river water contained 6.48 meq./l. of salt of which 24.69 per cent was sodium. The waters had a sufficiently

¹Analyses of the Solomon River water at Downs and Beloit were obtained from data supplied by the Kansas State Board of Health for the years 1957 and 1958. The averages reported in Table 15 are for the months May, June, July and August of these years.

high total salt content to be classified as medium in salinity hazard (15) although low in sodium hazard.

In addition to the water supplied by irrigation, the soils of Mitchell and Osborne Counties receive an average annual precipitation of about 25 inches, the bulk of which occurs in the normal 6-month growing season.

Salinity, Alkali and Calcium Carbonate Status of Soils. Overall increases in the salinity and alkali status of the irrigated profiles of sites 1 and 2 are indicated by a comparison of weighted means in Table 2.

Table 2. Weighted means of chemical analyses of soil horizons for irrigated and non-irrigated profiles and the average chemical analyses of irrigation waters used.

Site no.	Total soluble cations (meq./l.)	Soluble sodium per cent	Sodium adsorption ratio	Exchangeable sodium per cent
1. Water	5.15	28.54	1.03	
Irrigated soil	7.53	51.53	3.26	3.15
Non-irrigated soil	4.82	8.71	0.31	0.31
2. Water	6.48	24.69	1.03	
Irrigated soil	5.59	28.77	1.27	1.33
Non-irrigated soil	4.30	5.26	0.17	0.64
3. Water	6.48	24.69	1.03	
Irrigated soil	3.90	19.96	0.67	1.05
Non-irrigated soil	4.13	13.85	0.48	0.86

The chemical analyses (Table 2) also showed a slight increase in the sodium status of the irrigated profile of site 3, but little change in the salinity status. From Table 2 it is apparent that the greatest changes in salt and alkali status occurred at site 1 and the smallest at site 3 with site 2 being intermediate. This progressive decrease in the apparent

alkali and salinity effects of irrigation from sites 1 to 3 may be attributed to at least two interrelated factors. First, the progressive reduction in annual irrigation rates from sites 1 to 3 undoubtedly resulted in a corresponding reduction in the influence of the irrigation water on soil solution composition. This influence may be represented as a function of the ratio, average annual precipitation to the average annual irrigation rate (P/IR). In this particular case, the ratio of the average annual precipitation (P) to the average annual irrigation rate (IR) was inversely proportional to the changes noted in the soils. The ratios (P/IR) for sites 1, 2 and 3 were 1.0, 1.3 and 3.6, respectively. That is, the irrigated soils of sites 1, 2 and 3 received 1.0, 1.3 and 3.6 times more water annually from rainfall than from irrigation, respectively. This partially accounts for the progressive reduction in sodium and soluble salt accumulation, going from sites 1 to 3. Secondly, the soils became progressively coarser in texture in going from sites 1 to 3, thus permitting a correspondingly greater amount of leaching to occur with a resultant reduction in sodium and soluble salt accumulation.

In site 1 the greatest increases in salt and alkali content of the irrigated profile were found at depths between 6 and 25 inches. Restricted drainage in this area of the profile was apparently the cause of the increase in salt and sodium content. In sites 2 and 3 the uniformity of salt and alkali distribution throughout the profile was indicative of adequate leaching of the profile.

While there had been some increases in the soluble salts and exchangeable sodium in the irrigated profiles of sites 1 and 2, the alkali and salinity levels were well below critical levels.

The chemical analyses (Tables 16 & 17) give slight evidence of some CaCO_3 accumulation in the irrigated soils of sites 1 and 2. Site 1 shows an increase of .40 per cent and site 2 an increase of 2.11 per cent. Accumulation of calcium carbonate in site 1 also is supported by the fact that the soluble sodium percentage of the saturation extract was considerably higher than in the irrigation waters (Table 2), indicating that some of the calcium had precipitated from solution. At site 1 the soluble sodium increased from 23.5 per cent in the water to 51.5 per cent in the saturation extract of the soil. At site 2 soluble sodium increased from 24.7 per cent in the water to 28.8 per cent in the saturation extract. In contrast to sites 1 and 2, the chemical analyses for site 3 (Table 18) shows a reduction in CaCO_3 status of the irrigated soil, suggesting that dissolution of native carbonates may have occurred. This proposal is supported by the fact that the soluble sodium decreased from 24.7 per cent in the water to 19.9 per cent in the saturation extract (Table 2). It should be stressed, however, that while the alleged precipitations and dissolution of CaCO_3 may have occurred the differences noted in the calcium carbonate percentages may be largely or entirely due to native differences in the calcium carbonate status of the profiles. Measurable quantities of calcium carbonate ordinarily would not be expected to accumulate in or be lost from a profile in such a short period of time.

Relations between Soils and Waters. The TSCe/TSCiw , SSPe/SSPiw and SARe/SARiw ratios for the irrigated profiles of sites 1, 2 and 3 are given in Table 3. It is notable that all three of the ratios decreased progressively in size from sites 1 to 3. This probably was due to the progressive reduction in irrigation rates and the slight increase in soil

permeability from sites 1 to 3, as previously noted. The maximum increase in soluble salts occurred in site 1 where the saturation extract contained 1.52 times as much salt as the added irrigation water. The saturation extract of sites 2 and 3 contained less salt than that contained in the irrigation water because in each case the amount of rain falling on the soil actually exceeded the irrigation water applied. Therefore, it seems probable that under conditions of heavier irrigation and lighter rainfall, as would occur during periods of drought, that the TSCe/TSCiw ratio for sites 2 and 3 would increase somewhat above the values obtained.

Table 3. Ratios indicating relative composition of soil saturation extract and irrigation waters.

Site no.	$\frac{TSCe}{TSCiw}$	$\frac{SSPe}{SSPiw}$	$\frac{SARe}{SARiw}$
1.	$\frac{7.83}{5.15} = 1.52$	$\frac{51.53}{28.54} = 1.82$	$\frac{2.26}{1.06} = 3.03$
2.	$\frac{5.89}{6.48} = 0.91$	$\frac{28.77}{24.69} = 1.16$	$\frac{1.27}{1.03} = 1.23$
3.	$\frac{3.90}{6.48} = 0.60$	$\frac{19.96}{24.69} = 0.81$	$\frac{0.67}{1.03} = 0.65$

TSC = total soluble salt content, SSP = soluble sodium per cent,
SAR = sodium adsorption ratio.

Evidence has been cited previously which indicates that some of the calcium and magnesium added in the water to sites 1 and 2 had precipitated, thus increasing the per cent sodium. The SSPe/SSPiw ratio supports this since the per cent sodium in the saturation extract increased 1.82 and

1.16 times in sites 1 and 2, respectively, over that of the per cent sodium in the irrigation waters. A SSPe/SSPiw ratio of 0.81 in site 3 is indicative that the added water dissolved some of the native calcium compounds in the soil, thus lowering the per cent sodium in solution as the irrigation water changed into the soil solution or that native differences existed in the irrigated and non-irrigated soils.

Site 4; Soil - LM34D. Site 4 was located on the Gerald Smith farm in Mitchell County.

Salinity and Sodium Status of Waters. This particular soil was irrigated from a well at the rate of 18 acre-inches per year for 4 years prior to the time of sampling. Chemical analyses of the irrigation waters (Table 15) indicate a low sodium, high salinity status by accepted classification standards (15). That is, the water had an electrical conductivity of 803 micromhos per cm. of which 35.96 per cent was sodium.

Salinity, Alkali and Calcium Carbonate Status of Soils. The effect of the moderately slow permeability of the subsoil and the high salinity irrigation waters was evidenced by increases in the weighted means (Table 4) for per cent exchangeable sodium, the sodium adsorption ratio of the saturation extract, the total soluble salt content and the soluble sodium percentage of the irrigated soil.

Of interest was the higher native salt and alkali status of this soil as compared to the soils discussed previously. The mean soluble salt concentration of the saturation extracts of sites 1, 2 and 3 was 4.4 meq./l. whereas in site 4 it was 6.5 meq./l. The LM34D soil was on the average finer textured than the LM4X soil. Thus, decreased permeability was likely responsible for the larger content of salt and sodium found in this soil.

The salinity and alkali status of the irrigated profile of site 4 was still well below levels where crop production problems are anticipated.

Table 4. Weighted means of chemical analyses of soil horizons for irrigated and non-irrigated profiles and the average chemical analyses of irrigation waters used.

Site no.	Total soluble cations (meq./l.)	Soluble sodium per cent	Sodium adsorption ratio	Exchangeable sodium per cent
4. Water	10.15	35.96	2.04	
Irrigated soil	15.00	53.10	3.96	4.44
Non-irrigated soil	6.51	39.75	2.67	2.63
5. Water	19.04	47.06	4.00	
Irrigated soil	26.06	56.99	6.18	6.23
Non-irrigated soil	3.55	12.03	0.35	0.50

Despite the fact that there was a marked increase (from 35.96 to 53.10 per cent) in the relative sodium content of the saturation extract over that of the irrigation water, there was no evidence of any CaCO_3 accumulation. Undoubtedly, this was due to the fact that 4 years was insufficient time for measurable quantities of calcium carbonate to accumulate. Also, large native differences in CaCO_3 content seem to exist in all of the soils analyzed.

Relations between Soils and Waters. For site 4 the values of the TSCe/TSCiw , SSPe/SSPiw , SARe/SARiw ratios were 1.47, 1.47 and 1.92, respectively (Table 5). Since this soil has a finer textured subsoil than those of sites 1, 2 and 3, it seems probable that under normal field conditions and with continued application of similar water the ratios TSCe/TSCiw and SARe/SARiw will increase somewhat.

Table 5. Ratios indicating relative composition of soil saturation extract and irrigation waters.

Site no.	$\frac{TSCe}{TSGiw}$	$\frac{SSPe}{SSPiw}$	$\frac{SARE}{SARIw}$
4.	$\frac{15.00}{10.15} = 1.47$	$\frac{53.10}{35.95} = 1.47$	$\frac{3.96}{2.04} = 1.92$
5.	$\frac{26.06}{19.04} = 1.37$	$\frac{56.99}{47.06} = 1.20$	$\frac{6.18}{4.00} = 1.54$

Site 5; Soil - MLX. Site 5 was located on the Henry Remus farm in Mitchell County.

Salinity and Sodium Status of Waters. This particular soil was irrigated by well for three years prior to the 1958 growing season and received no irrigation waters in 1958 because of the high rainfall of that season. According to the analyses (Table 15), the well water has an electrical conductivity of 1900 micromhos per cm. and a sodium adsorption ratio of 4.00; consequently, it would be classed as a high salinity, low sodium water (15).

Salinity, Alkali and Calcium Carbonate Status of Soil. As indicated previously, the soil (MLX) is characterized by fine texture and very slow permeability. The restricted internal drainage of this soil was reflected clearly by marked increases (Table 4) in the salinity and alkali status of the irrigated profile. The soluble salt content of the saturation extract increased from 3.55 to 26.06 meq./l. The mean exchangeable sodium percentage increased from 0.50 in the non-irrigated soil to 6.23 in the irrigated soil.

The irrigated profile shows a progressive increase in salinity with increasing depth down to 36 inches where the soil was saline with an electrical conductivity of 4.050 millimhos per cm. (Table 20). This compares with an electrical conductivity of 0.295 millimhos per cm. at a corresponding point in the non-irrigated profile. Similarly, the analysis (Table 20) shows an increase in the exchangeable sodium percentage with depth with a maximum of 10.9% at the 36 to 46-inch depth. The progressive increase in the salinity and alkali status with depth in the profile may be attributed chiefly to restricted drainage due to the fine clay horizon in this part of the profile.

The chemical analysis indicated a deposition of 15.25 meq. of gypsum per 100 grams of soil at the 26 to 36-inch depth; however, an insufficient quantity of irrigation water was applied to account for this amount of gypsum.

Judging from the analyses the sodium and soluble salt status of the surface soil was not sufficiently high to retard growth or restrict yields of most crop plants; however, it seems inevitable that, with continued use of the high salinity water and without improved drainage, the salt status could easily approach hazardous levels.

The analyses (Table 20) show that the irrigated profile contains 1.81 per cent more calcium carbonate than the non-irrigated profile. Obviously, differences of this magnitude could not occur from 3 years of irrigation; consequently, it was concluded that native differences existed.

Relations between Soils and Waters. For site 5 the TSCe/TSC1w, SSPe/SSP1w, SARE/SAR1w ratios were 1.37, 1.20 and 1.54, respectively (Table 5). All three of these ratios would be expected to increase in value with continued application of similar waters since the deep clay subsoil apparently has not permitted adequate leaching of the profile.

The remarkably low ratios, considering the fine textured subsoils, which were obtained can probably be ascribed to the short period of irrigation. That is, insufficient waters were applied during the 3 years of irrigation to increase the ratios above their present values.

Finney, Grant and Kearny Counties
Sites 6, 7 and 8; Soil Series - "Richfield"

Site 6 was located on the Boyd farm and on Garden City Company land in Finney County. Site 7 was located on the Welland farm in Finney County and on the Garden City Company land in Kearny County. Site 8 was located on the Ralph Tuttle and R. Elehm farms in Grant County.

Salinity and Sodium Status of Waters. The irrigated soil of site 6 has received water from the Great Eastern Ditch¹ (direct from the Arkansas River) for nearly 50 years and from a well for at least the past 3 years. The ditch and well water contained 41.2 and 20.7 per cent sodium and had an electrical conductivity of 2263 and 723 micromhos per cm., respectively (Table 15). On this basis the ditch and well waters would be classified

¹Analyses of the Arkansas River at Dodge City, which were furnished by the Kansas State Board of Health, were used to represent the composition of the Great Eastern Ditch waters. The analyses given in Table 15 represent the average composition of the Arkansas River waters for May, June, July and August of 1957 and 1958.

as high salinity, low sodium and low sodium, medium salinity waters, respectively.

Site 7 included a soil irrigated with water from the Great Eastern Ditch for 52 years and a comparison soil irrigated by well for only 13 years. No analysis was made on the water from this particular well.

The irrigated profile of site 8 had received well water for 15 years. The analyses (Table 15) indicated that the water contained 28.2 per cent sodium and had an electrical conductivity of 555 micromhos per cm. On this basis the water would be ranked as low in sodium hazard and medium in salinity hazard.

Besides the waters supplied by irrigation the soils of these sites receive an average annual precipitation of from 15 to 20 inches, most of which comes during the normal 6-month growing season.

Salinity, Alkali and Calcium Carbonate Status of Soils. The summary of the chemical analyses for sites 6, 7 and 8 (Table 6) show moderate increases in the salinity and sodium status of the irrigated profiles of sites 6 and 8. The summary also indicates a higher salinity and alkali status for the soil profile of site 7 which received the high salinity ditch waters, as compared to the profile irrigated by well water. For example, the exchangeable sodium percentage and the total salt content of the ditch-irrigated profile were roughly twice as large as corresponding values for the profile irrigated by well (Table 6).

The soil of site 6, which had been irrigated with the poor quality Arkansas River water for 50 years and then with well water for at least 3 years, reflected most strongly the influence of the well water. The well water contained 6.92 meq./l. of soluble salt of which 20.66 per cent

was sodium. The mean salt content of the saturation extract of the soil was 7.07 meq./l. of which 25.19 per cent was sodium. These values are very low compared with the 38.9 meq./l. of salt and 46.84 per cent sodium which occurred in the saturation extract of site 7 which was irrigated entirely with river water. Since the well water used on the soil of site 6 was much lower in both salt and sodium than the river water, it is logical to assume that the soil had received enough of the better quality well water to materially affect its properties. It is unfortunate that it was not known exactly how much irrigation water the soil received from the well.

Table 6. Weighted means of chemical analyses of soil horizons for irrigated and non-irrigated profiles and the average chemical analyses of irrigation waters used.

Site no.	Total soluble cations (meq./l.)	Soluble sodium per cent	Sodium adsorption ratio	Exchangeable sodium per cent
6. Water (river)	22.83	40.19	3.67	
Water (well)	6.92	20.66	0.87	
Irrigated soil	7.07	25.19*	1.15*	1.34*
Non-irrigated soil	4.88	7.02*	0.25*	0.68*
7. Water (river)	22.83	41.19	3.63	
Water (well)				
Irrigated soil (river)	38.90	46.84	5.84	5.18
Irrigated soil (well)	17.35	33.33	2.65	2.55
8. Water	5.82	28.18	1.15	
Irrigated soil	7.60	22.57	1.46	1.79
Non-irrigated soil	5.09	10.01	0.35	0.62

*These values were calculated to give the weighted means to 40-inch depth in the profile instead of in accordance with the method described on page 16 since that method yielded values not representative of the alkali status of the main root zone.

That soil in site 7 which was irrigated by well water of unknown quality contained a mean of 17.35 meq./l. of soluble salts (Table 6). This was over twice the amount of soluble salts contained by the two other "Richfield" soils from sites 6 and 8 which were irrigated with well water. The reasons for this cannot be known since the quality of the water was not known but two likely possibilities are as follows: (1) the water contained a large amount of soluble salts, (2) the internal drainage of this particular "Richfield" soil is poorer than the other soils selected.

The sodium and soluble salt status of both of the profiles of sites 6 and 8 were well below levels at which problems are expected to develop. However, at site 7 both the soil irrigated from the river and from the well show detrimental accumulations of salt. Below the 14-inch depth in the well-irrigated profile of site 7 the mean electrical conductivity of the saturation extract was about 2 millimhos per cm., the point at which the yields of many sensitive crops are restricted (15). Electrical conductivity determinations (Table 22) indicate that the salt status of the ditch-irrigated profile of site 7 was sufficiently high to restrict the yields of many crops, i.e., the electrical conductivity was greater than 4 millimhos per cm.

Data (Table 21) for the irrigated profile of site 6 show an overall calcium carbonate status slightly above that of the non-irrigated profile. The calcium carbonate per cent of the ditch-irrigated profile of site 7 was 1.26 per cent above that of the profile irrigated by well; however, this difference is too great to be accounted for entirely by additions from irrigation waters. Consequently, native differences in the profiles must be concluded. The data also indicate marked differences between the calcium

carbonate status of the profiles of site 8 (Table 23). In this case the overall calcium carbonate percentage of the irrigated soil was 2.85 per cent below that of the non-irrigated soil. Again, such large differences must be ascribed to native differences in calcium carbonate content.

Relations Between Soils and Waters. The ratios $TSCe/TSCiw$, $SSPe/SSPiw$ and $SARe/SARiw$ for the river waters and the soil saturation extract of site 6 were equal to 0.31, 0.63 and 0.31, respectively (Table 7). These ratios were remarkably low considering the fact that the irrigated soil of site 6 has received river water for the past 50 years. This same soil has been irrigated with well water for at least the past 3 years. The $TSCe/TSCiw$, $SSPe/SSPiw$ and $SARe/SARiw$ ratios for this soil, figured on the basis of the composition of the well water, were 1.02, 1.22 and 1.32, respectively. These latter ratios are much more logical than those obtained on the basis of the river water because it is very unusual for the salt content of the saturation extract to be lower than that present in the irrigation water. This fact would suggest that the soil solution was much more nearly in equilibrium with the well water than with the river water.

Table 7. Ratios indicating relative composition of soil saturation extract and irrigation waters.

Site no.	$\frac{TSCe}{TSCiw}$	$\frac{SSPe}{SSPiw}$	$\frac{SARe}{SARiw}$
6. River	$\frac{7.07}{22.83} = 0.31$	$\frac{25.19}{40.19} = 0.63$	$\frac{1.15}{3.67} = 0.31$
Well	$\frac{7.07}{6.92} = 1.02$	$\frac{25.19}{20.66} = 1.22$	$\frac{1.15}{0.87} = 1.32$
7. River	$\frac{22.83}{17.35} = 1.69$	$\frac{41.19}{33.33} = 1.23$	$\frac{2.63}{2.65} = 1.37$
8.	$\frac{7.60}{5.82} = 1.30$	$\frac{28.57}{28.18} = 1.01$	$\frac{1.46}{1.15} = 1.27$

The ratios for sites 7 and 8 indicate that the total salt present in the saturation extract increased 1.69 and 1.30 times, respectively, over that present in the irrigation waters. The sodium present in the saturation extract of the river-irrigated soil of site 7 was 1.23 times higher than that in the added water. In the well-irrigated soil of site 8 the per cent sodium in the saturation extract and in the irrigation water was about the same. All of the ratios; $TSCe/TSCiw$, $SSPe/SSPiw$ and $SARE/SARiw$; from the river-irrigated "Richfield" soil of site 7 are higher than those from the other sites. This can be attributed to the poor quality of water used and also to a reported deposition of clay from the river on the surface of this soil. Such a deposition would slow the leaching process.

Haskell County
Sites 9, 10 and 11; Soil Series - "Spearville"

Sites 9, 10 and 11 were located on the Kelly McClure farm, the A. B. Sherwood farm and the Waldron farm, respectively.

Salinity and Sodium Status of Waters. The soils of sites 9, 10 and 11, tentatively classified as "Spearville silty clay loam", have been irrigated for 9, 5 out of 9, and 10 years, respectively. Irrigation of these sites was with good quality water from wells having electrical conductivities ranging from 300 to 400 micromhos per cm. and sodium percentages below 30 (Table 15). These waters, according to accepted standards (15), would be classified as low sodium, medium salinity waters.

In addition to the irrigation waters the soils of these sites in Haskell County receive an average annual precipitation of 18 inches, three-fourths of which occurs during the growing season.

Salinity, Alkali and Calcium Carbonate Status of Soils. A comparison of weighted means for various determinations (Table 8) would indicate a small reduction in the salinity and alkali status of the irrigated profiles of sites 9 and 11, apparently due to the loss of native salts from the profiles by leaching. This reduction in the salinity and alkali status can be attributed to the high native salt and alkali content of the soil as compared with the salt and alkali content of the irrigation waters.

Table 8. Weighted means of chemical analyses of soil horizons for irrigated and non-irrigated profiles and the average chemical analyses of irrigation waters used.

Site no.	Total soluble cations (meq./l.)	Soluble sodium per cent	Sodium adsorption ratio	Exchangeable sodium per cent
9. Water	3.51	29.17	0.79	
Irrigated soil	16.81	40.34	3.02	2.60
Non-irrigated soil	20.59	41.27	3.63	3.50
10. Water	3.30	21.21	0.62	
Irrigated soil	14.31	43.18	3.38	3.23
Non-irrigated soil	7.27	32.17	1.92	1.52
11. Water	2.82	26.60	0.75	
Irrigated soil	13.72	37.00	2.78	2.81
Non-irrigated soil	23.95	39.50	3.53	3.06

It is of interest to note that the "Spearville" soils (sites 9 and 11) have about 4 times more native salts (Tables 6 & 8) than the "Richfield" soils previously discussed. This difference probably was due to the relatively finer textured B horizon of the "Spearville" soils. The irrigated profile of site 10 contained essentially the same amount of soluble salts as did the irrigated soils of sites 9 and 11. The irrigated soil of site 10, in contrast

with sites 9 and 11, showed a moderate increase in overall salinity and alkali status. However, there are several indications of native textural differences in the comparison profiles which could account for the apparent soluble salt and sodium increases. One indication of textural differences is that the salt distribution (appendix, p. 110) within the non-irrigated soil of site 10 deviates from the general pattern set by the rest of the irrigated and non-irrigated "Spearville" profiles. That is, the distribution of salts in the non-irrigated profile of site 10 was more or less uniform throughout the entire profile whereas there was a marked rise in salinity below the 24-inch depth in the rest of the profiles of sites 9, 10 and 11 (Tables 24-26). Likewise, the profile descriptions (appendix, p. 107-112) indicated that the profiles of sites 9, 10 and 11 were quite similar with regard to texture at corresponding depths with the exception of the lower portion of the non-irrigated profile of site 10 which was relatively coarser in texture. Therefore, it seems likely that improved internal drainage was the result of the coarser textured horizons in the lower portion of site 10. This would account for the lower salt content of the non-irrigated profile of site 10.

A comparison of the salt distribution (Tables 24 & 26) of corresponding irrigated and non-irrigated profiles of sites 9 and 11 shows a general movement of native soluble salts downward with the application of irrigation water. The reductions in the mean soluble salt content of sites 9 and 11 were 3.78 and 10.23 meq./l., respectively (Table 8). The salt distribution of the non-irrigated profiles of sites 9 and 11 indicates that under native conditions water from precipitation ordinarily leaches the soluble salts to about a 4-foot depth.

The sodium and salt content in the first 2 feet of both the irrigated and non-irrigated profiles of sites 9, 10 and 11 were well below the levels where deleterious effects are noted. However, below this depth, the salinity status of the soil quickly approached hazardous levels as denoted by electrical conductivity values of the saturation extract of from 3 to 4 millimhos per cm. (Tables 24-26). If it is assumed that the irrigated "Spearville" soil of site 10 was originally comparable in salt content to the non-irrigated soils of sites 9 and 11, then none of the irrigated sites are higher in salt in the lower depths than the non-irrigated soils.

Little can be concluded from the data (Tables 24-26) with regard to any possible effects of irrigation on the calcium carbonate status of the comparison sites 9, 10 and 11 due to apparent large differences in the native calcium carbonate status of the soils. Tables 24-26 show the overall differences in calcium carbonate content to be greater than 4 per cent for the comparison profiles of sites 9 and 10 and the difference to be greater than 1 per cent for site 11.

Relations between Soils and Waters. The TSCe/TSCiw ratios for sites 9, 10 and 11 were 4.76, 4.35 and 4.76, respectively (Table 9). The more than 4-fold greater concentration of the irrigation waters as compared with saturation extracts may be attributed to the high native salinity of the soils and the low salt content of the waters. As previously noted, some reduction in native salt content already had occurred since irrigation began in the soils of sites 9 and 11. With continued irrigation with waters of similar quality and with adequate leaching of the profile, the TSCe/TSCiw ratio for sites 9, 10 and 11 likely would be reduced considerably;

however, adequate leaching may be difficult to achieve due to the clay subsoils.

Table 9. Ratios indicating relative composition of soil saturation extract and irrigation waters.

Site no.	$\frac{TSCe}{TSCiw}$	$\frac{SSPe}{SSPiw}$	$\frac{SARe}{SARiw}$
9.	$\frac{16.81}{3.51} = 4.76$	$\frac{40.34}{29.17} = 1.39$	$\frac{3.02}{0.79} = 3.85$
10.	$\frac{14.31}{3.30} = 4.35$	$\frac{43.18}{21.21} = 2.04$	$\frac{3.38}{0.68} = 5.55$
11.	$\frac{13.72}{2.82} = 4.76$	$\frac{37.00}{26.60} = 1.35$	$\frac{2.78}{0.75} = 3.70$

Sites of Hamilton County

Site 12; Soil Series - "Syracuse." Site 12 was located on the Baldwin, Armstrong and Wagoner farms.

Salinity and Sodium Status of Waters. Site 12 involved a three-way comparison of a soil irrigated by water from the Arkansas River for 25 to 50 years, a soil irrigated by well water for 12 years and a non-irrigated soil, all of the same soil type. The supply canal from the Arkansas River, reportedly, at times picked up drainage water from the Colorado irrigation systems. The analyses of the well and Arkansas River waters at Dodge City (Table 15) indicate that both waters would be placed in the low sodium, very high salinity class.

In addition to irrigation waters, the soils of Hamilton County receive an average annual precipitation of 17 inches, over three-fourths of which comes during the normal growing season.

Salinity, Alkali and Calcium Carbonate Status of Soils. Chemical analyses (Table 10) indicated hazardous levels of soluble salts in both the river-irrigated profile and the profile irrigated by well which was evidently attributable to the very high salinity irrigation waters. Surprisingly, the salinity status (Table 10) of the soil irrigated by well was appreciably below that of the river-irrigated soil, despite the fact that the well water contained nearly 3 times more soluble salt than the river water.

The lower than expected soluble salt status of the profile receiving well water may have been due to (1) a low rate of irrigation combined with higher than normal rainfall or (2) better permeability in the well-irrigated soil than in the river-irrigated soil. The profile descriptions, however, indicate little difference in the overall texture of the two profiles. Both profiles have a clay loam textured horizon near the surface which grades into a loam at greater depths in the profile.

The data in Table 10 show an increase in the sodium content of both the well-irrigated and river-irrigated profiles with the greatest increase occurring in the latter.

The uniform distribution of soluble salts and sodium (Table 27) within the irrigated profiles of site 12 suggests that no single horizon was the major cause of the salt build-up. The increased salt most likely was due to the extremely poor quality of the water used. The well water is of such poor quality that leaching the soil with this water would increase the salt content of the soil even over its present high salt content.

The alkali status of two irrigated profiles of this site was appreciably below the point where soil problems develop; however, a somewhat different picture was indicated with regard to the salinity levels. The

salinity level (Table 27) of the profile irrigated by well was sufficiently high to restrict the yields of many sensitive crops, whereas the salinity status of the river-irrigated soil was high enough to restrict the yield of many crops according to the classification system used by the U. S. Salinity Laboratory wherein the electrical conductivity of the saturation extract is correlated to crop response (15).

Table 10. Weighted means of chemical analyses of soil horizons for irrigated and non-irrigated profiles and the average chemical analyses of irrigation waters used.

Site no.	Total soluble cations (meq./l.)	Soluble sodium per cent	Sodium adsorption ratio	Exchangeable sodium per cent
12. Water (river)	22.83	41.19	3.63	
Water (well)	62.48	43.51	6.50	
Irrigated soil (river)	46.17	48.55	6.34	5.97
Irrigated soil (well)	38.67	48.66	6.05	4.97
Non-irrigated soil	7.95	38.17	3.64	
13. Water	50.59	43.06	5.80	
Irrigated soil	9.02	59.30	4.15	4.53
Non-irrigated soil	48.32	61.14	11.13	8.93

The data (Table 27) reveal sufficiently large variations in the calcium carbonate status of the 3 profiles of site 12 to suggest native differences. Small amounts of gypsum were found in the horizons of the irrigated soils where the electrical conductivity of the saturation extracts exceeded 4 millimhos per cm.

Relations between Soils and Waters. The ratios $TSCe/TSCiw$, $SSPe/SSPiw$ and $SARE/SARiw$ for the river-irrigated soil of site 12 were equal to 2.04, 1.18 and 1.75, respectively (Table 11). According to past studies (15),

these ratios compare very favorably with what would be expected in well drained soils irrigated for long periods of time. However, the $TSCe/TSCiw$ ratio of the well-irrigated soil was much lower than what would be expected (Table 11). Continued irrigation with similar waters likely will increase the ratio appreciably above the obtained value of 0.62, especially if large amounts of irrigation water are used.

Table 11. Ratios indicating relative composition of soil saturation extract and irrigation waters.

Site no.	$\frac{TSCe}{TSCiw}$	$\frac{SSPe}{SSPiw}$	$\frac{SARe}{SARiw}$
12. River	$\frac{46.17}{22.83} = 2.04$	$\frac{48.19}{41.19} = 1.18$	$\frac{6.34}{3.63} = 1.75$
Well	$\frac{38.67}{62.48} = 0.62$	$\frac{48.66}{43.51} = 1.12$	$\frac{6.05}{6.50} = 0.93$
13.	$\frac{9.02}{50.59} = 0.18$	$\frac{59.20}{43.06} = 1.37$	$\frac{4.15}{5.80} = 0.71$

Site 13; Soil Series - "Las Animas." Site 13 was located on the Squire farm and Shatterly ranch.

Salinity and Sodium Status of Waters. The irrigated profile of site 13 has received very high salinity waters (Table 15) from wells, intermittently, since 1951; however, the salt balance was favorable as evidenced by a soluble sodium percentage of 43.06.

Salinity, Alkali and Calcium Carbonate Status of Soils. Table 10 indicated a surprisingly low salinity and alkali content of the irrigated profile in comparison with the non-irrigated profile, considering the very high salinity of the irrigation waters. It is inconceivable that an irrigation water containing 50.59 meq./l. of soluble salts could effect a reduction in salt content of a saturation extract from 48.32 meq./l. to 9.02 meq./l. Consequently, it must be concluded that native differences existed in the salinity status of the profiles and only a small amount of irrigation water was applied, and/or the salt content of the irrigation water samples which were analyzed was much higher than the average of the waters which had leached through the soil. Without additional information a fully plausible explanation of the data referred to above was not possible.

The soluble salt content and the exchangeable sodium percentage (Table 10) of the irrigated profile were well below the levels at which problems are encountered. The mean soluble salt content of the saturation extract was 9.02 meq./l. (Table 10) and the exchangeable sodium per cent was 4.53.

The analyses show that hazardous levels of soluble salts and exchangeable sodium were present in the non-irrigated profile between 16 and 29 inches deep. Here the electrical conductivity of the saturation extract was 6.87 millimhos per cm. and the exchangeable sodium percentage was 15.36. An electrical conductivity of this magnitude would be expected to limit the yields of many crops. Despite the high exchangeable sodium percentage, dispersion of the soil colloids would not be anticipated because of the high soluble salt content of the saturation extract.

The data (Table 28) show an overall reduction of .39 per cent in the calcium carbonate content of the irrigated profile; however, native profile differences probably accounted for this variation.

Relations between Soils and Waters. The saturation extract and irrigation waters of the irrigated profile of site 13 definitely were not in equilibrium as indicated by a $TSCe/TSCiw$ ratio of only 0.18 (Table 11). Such a low ratio may have resulted from the application of very little irrigation water or from a rather thorough leaching of the profile with rain water.

Stevens County
Site 14; Soil Series - Ulysses

Site 14 was located on the Parsons Brothers farm and the Kenoyer farm.

Salinity and Sodium Status of Waters. Site 14 has been irrigated since 1940 with well water which has a low sodium and medium salinity classification. The water contained 5.32 meq./l. of salt of which 32.5 per cent was sodium (Table 12). In addition to irrigation waters these soils receive an average annual precipitation of about 17 inches.

Salinity, Alkali and Calcium Carbonate Status of Soils. Apparently there had been very little change in the salinity and alkali levels of the irrigated soil, judging from the similar weighted mean values for corresponding determinations given in Table 12. From the standpoint of distribution, it is apparent from the data (Table 29) that the bulk of the sodium in the non-irrigated soil was concentrated at the bottom of the profile whereas sodium was distributed more evenly in the irrigated profile. Adequate leaching probably accounted for this uniform distribution.

Table 12. Weighted means of chemical analyses of soil horizons for irrigated and non-irrigated profiles and the average chemical analyses of irrigation waters used.

Site no.	Total soluble cations (meq./l.)	Soluble sodium per cent	Sodium adsorption ratio	Exchangeable sodium per cent
14. Water	5.32	32.52	1.31	
Irrigated soil	6.00	29.43	1.25	1.39
Non-irrigated soil	6.37	26.69	1.50	2.16

Salinity and alkali levels (Table 12) of both profiles (irrigated and non-irrigated) were well below the levels at which problems develop.

The differences between the overall calcium carbonate status of the irrigated and non-irrigated profiles was of such magnitude (2.35 per cent) that native differences were concluded.

Relations between Soils and Waters. The ratios $TSCe/TSCiw$, $SSPe/SSPiw$ and $SARE/SARiw$ for site 14 were equal to 1.12, 0.91 and 0.95, respectively. These ratios indicate that the relative composition of irrigation waters and the saturation extract were quite similar.

Correlation and Regression Studies

Relation between Soil and Water Characteristics. The fact that relationships do exist between the chemical characteristics of soils and corresponding irrigation waters has been well established by past investigations (9, 15). The closeness of the relationships, obviously, is a measure of the degree of equilibration between the waters and soils. Generally, past studies have shown that the closeness of the relationship between the chemical characteristics of soils and waters increases with increased soil permeability and also is dependent to a certain extent on the rate and years of irrigation.

To evaluate the closeness of the relationship between chemical determinations made on the soils and waters of this study, correlation coefficients were calculated from the data for the following: (1) sodium adsorption ratio of irrigation water and the exchangeable sodium percentage of the entire profile; (2) sodium adsorption ratio of irrigation water and the mean exchangeable sodium percentage of the first 24 inches of the profile; (3) total soluble cation content of irrigation water and the mean soluble cation content of the saturation extract for the entire profile; (4) sodium percentage of irrigation water and the mean sodium percentage of the saturation extract for the entire profile. Weighted means were employed to represent the soil and saturation extract determinations involved in the above relationships. All of the irrigated profiles which were sampled were included in the calculations.

Highly significant correlation coefficients were obtained for the relationships listed above and in Table 13 except for No. 3 which was significant merely at the 5 per cent level.

Table 13. Correlation and regression coefficients and the standard deviations from regression for the relation of various soil and irrigation water determinations.

Chemical determinations		Depth of soil	Sample correlation coefficient (r)	Regression equation ($\hat{Y} = bX + a$)	Std. deviation from regression ($s_{y.x}$)
Irrigation waters (Y)	Soil or saturation extract (X)				
Weighted means					
1. SAR _{iw}	ESP	Entire profile	.716**	$\hat{Y} = 0.763X + 0.182$	1.343
2. SAR _{iw}	ESP	0-24 in.	.732**	$\hat{Y} = 0.937X - 0.032$	1.311
3. TSC _{iw}	TSC _e	Entire profile	.601*	$\hat{Y} = 0.665X + 4.952$	5.997
4. SSP _{iw}	SSP _e	Entire profile	.696**	$\hat{Y} = 0.454X + 14.506$	12.228

SAR = sodium adsorption ratio, ESP = exchangeable sodium percentage, TSC = total soluble cations (meq./l.), SSP = soluble sodium percentage, iw = irrigation water, e = saturation extract, $\hat{Y}$ = estimated values of Y from regression equation, b = sample regression coefficient, a = y-intercept of sample regression line.

* Significant at .05 level.

** Significant at .01 level.

It appears that the relatively high correlation coefficients indicate an overall trend toward equilibrium between the irrigation waters and soils.

Higher correlation coefficients would not have been anticipated considering the short period of irrigation and the restricted drainage of some of the soils. The slightly higher correlation coefficient (Table 13) of SAR_{iw} and ESP for the upper 2 feet of the profile compared with the entire profile would suggest that the cations in the irrigation waters were slightly nearer in equilibrium with the adsorbed cations near the surface of the soil than at greater depths.

To determine the way in which the correlated soil and irrigation water determinations were related, regression equations were determined for the regression of irrigation water determinations (Y) on soil determinations (X). These equations and the standard deviations from regression also are included in Table 13.

The relatively smaller regression coefficient (b, in the regression equations, Table 13) of the regression of SARIw on ESP for the entire profile compared with the regression of the top 2 feet was evidently attributable to the general trend of increasing ESP values with depth in the profile. A comparison of the standard deviations from the regression of SARIw on ESP (Table 13) shows greater average deviations from the trend line for the entire profile than for the upper 2 feet, again, apparently reflecting a slightly higher degree of equilibration in the surface 2 feet.

Relation between SAR of Saturation Extract and ESP. To study the relationship between the sodium adsorption ratio of the saturation extract and the exchangeable sodium percentage, correlation coefficients and regression equations were determined for the horizons of all profiles sampled, both irrigated and non-irrigated; for the horizons of all the irrigated profiles and for the horizons of the non-irrigated profiles. Also, the standard deviations from regression ($s_{y,x}$) and the standard error of the regression coefficient (s_b) were determined to obtain a measure of the average deviation of the SAR values from the trend line and of the reliability of the slope of the trend line. The results of these determinations appear in Table 14.

Table 14. Relation between the sodium adsorption ratio of the saturation extract (SAR_e) and exchangeable sodium percentage (ESP).

Soil horizons included	Correlation coefficient (r)	Regression equation ($\hat{Y} = bX + a$)	Std. deviation from regression ($s_{y,x}$)	Std. deviation of regression coefficient (s_b)
Horizons of all profiles sampled	0.956***	$\hat{Y} = 1.125X - 0.288$	0.824	0.027
Horizons of all irrigated profiles	0.950***	$\hat{Y} = 1.041X - 0.073$	0.699	0.035
Horizons of all non-irrigated profiles	0.961***	$\hat{Y} = 1.210X - 0.382$	0.867	0.039

$Y = SAR$, $X = ESP$, $\hat{Y}$ = estimated values of Y from regression equation, a = y -intercept of sample regression line, b = sample regression coefficient.

*** Significant at the .001 level.

Highly significant correlation coefficients (Table 14) were obtained for the relation between the sodium adsorption ratio of the saturation extract (SAR_e) and the exchangeable sodium percentage (ESP) for both irrigated and non-irrigated soils. A slightly higher correlation coefficient was obtained for the non-irrigated soils which may be attributable to a slightly greater exchange equilibria in these soils. The high correlation coefficients, low standard deviations from regression, and low standard deviations of the regression coefficient (Table 14) suggest that a fair degree of accuracy could be achieved in the prediction of exchangeable sodium percentage from the analyses of the saturation extract of both irrigated and non-irrigated soils. However, if it were desired to predict

the ESP of the soil from the SAR of the saturation extract the regression equation of ESP on SAR_e should be determined, i.e., ESP should be treated as the dependent variable.¹

Figure 3 is a plot of the trend line for the relation obtained between the sodium adsorption ratio of the saturation extract and the exchangeable sodium percentage for all horizons of all profiles sampled.

¹ESP was treated as the independent variable in the regressions in this thesis to facilitate comparisons with past investigations in which ESP was treated in this manner.

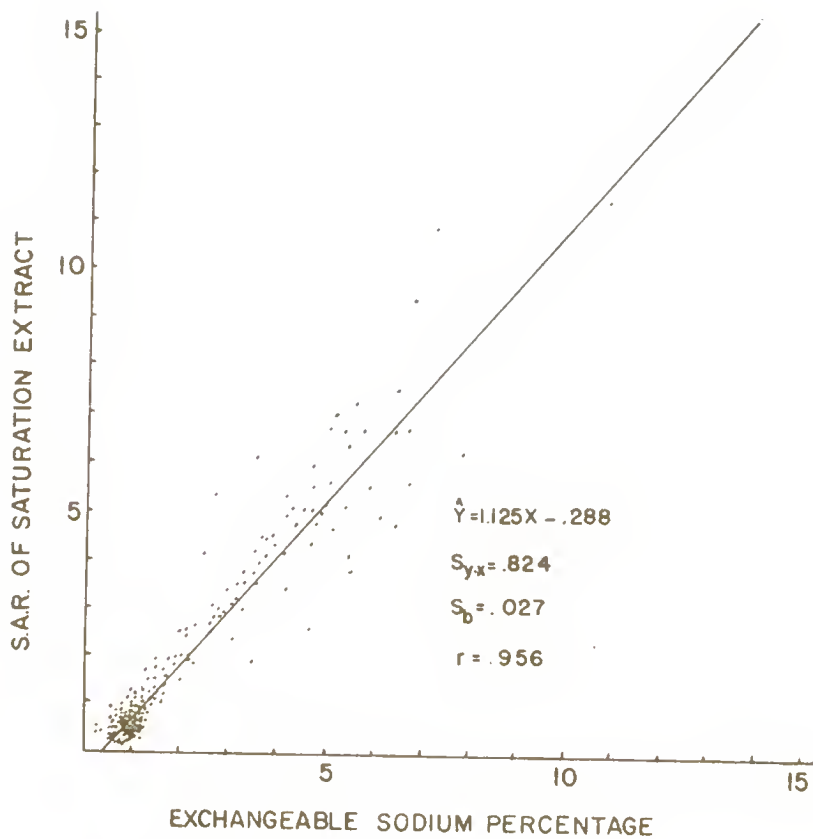


Figure 3. Relationship between the sodium adsorption ratio of the saturation extract and the exchangeable sodium percentage for irrigated and non-irrigated soils.

SUMMARY

This study was undertaken to determine the effects of irrigation on the chemical properties of the soils of two of the major irrigated sections of the state - North Central and Southwestern Kansas. Primary consideration was given to changes in the soluble salt and alkali status of the irrigated soils. Fourteen soil sampling sites were selected as representative of large acreages under irrigation. From each site an irrigated and a non-irrigated or a short-time irrigated comparison soil were sampled by horizon to near 5-foot depths. Five sites were located in North Central Kansas - 4 in Mitchell County and 1 in Osborne County. The remaining 9 sites were located in Southwestern Kansas - 3 in Finney, Kearny and Grant Counties, 3 in Haskell County, 2 in Hamilton County and 1 in Stevens County.

Well water samples were obtained and analyzed, while river water analyses were supplied by the Kansas State Department of Health.

The following chemical analyses were made: pH of irrigation water, saturated paste, and saturation extract; electrical conductivity of irrigation water and saturation extract; major water soluble cations and anions in irrigation water and saturation extract; ammonium acetate extractable cations of the soil; and gypsum and calcium carbonate equivalent of the soil. Water soluble and ammonium acetate extractable cations were determined directly by a flame photometer. Carbonate and bicarbonate were determined by titration with acid and chloride by titration with silver nitrate. Sulfate was determined conductrimetrically as calcium sulfate. The cation exchange capacity was determined by first leaching with sodium acetate, washing with alcohol, leaching with ammonium acetate to remove the adsorbed sodium, and then by analyzing directly for sodium by the flame photometer.

The soil analyses showed slight increases in the soluble salt and alkali content of 2 of 3 of the irrigated IM4I profiles (sites 1, 2 and 3) representing the Solomon River Valley alluvium with little or no change in the other. The soluble salt and sodium levels in all 3 profiles were well below hazardous levels.

Increases in salinity and exchangeable sodium were indicated by the analyses for the irrigated profiles of soil IM34D at site 4, and soil IMIX at site 5, with the greatest increases being in the latter soil which had the lowest permeability. Sodium levels in both irrigated soils were still very low. The soluble salt content of the irrigated profile of site 4 was also quite low; however, soluble salts had accumulated in the irrigated profile of site 5 to a hazardous level below 26 inches deep. This accumulation was attributed to the combined effect of high salinity waters and restricted internal drainage.

Slight increases in the salinity and alkali levels were indicated by the analyses of the "Richfield" series irrigated soils of sites 6 and 8. Even though there was a small increase in the salinity status of the irrigated soil of site 6, the soluble salt content of the saturation extract was remarkably low, considering the very high salinity river waters used for irrigation for more than 50 years. The results indicated that the soil solution was nearer in equilibrium with the well water which had been used on this soil for at least 3 years and perhaps longer. The salinity and alkali status of sites 6 and 8 still was very low. The salinity and alkali status of the well-irrigated "Richfield" soil of site 7 was considerably lower than that of the river-irrigated soil of the same site. The soluble salt content of the well-irrigated soil and the alkali content of

both profiles of site 7 were well below the critical levels; however, the salt content of the river-irrigated soil was at a hazardous level.

Analyses of the "Spearville" series soils of sites 9, 10 and 11 indicated that irrigation waters effected a reduction in the soluble salts and alkali content of sites 9 and 11 with a slight gain in site 10. The gain registered in site 10 probably was not real because the comparison non-irrigated soil at this site was coarser in texture than the other soils and contained less native salt originally. The reduction in salinity of sites 9 and 11 was attributed mainly to the good quality irrigation waters and to the comparatively high native salinity of the soils. The salinity and alkali status in these soils was well below critical levels in the main root zone.

Increases were indicated by the analyses in the soluble salt and alkali status of both the well and river-irrigated soils of the "Syracuse" series (site 12) with the greater increase in salinity having occurred in the river-irrigated soil. This was true in spite of the fact that the river water was the less saline of the two waters. The soluble salt content of both irrigated soils was near or at hazardous levels. The quality of water used on these soils was very poor and a similar salt build-up would not be expected if good quality water were used.

The analyses for the irrigated profile of the "Las Animas" soils (site 13) indicated a surprisingly low salinity status considering the very high salinity of the irrigation waters. Original differences between the irrigated and non-irrigated profiles were suggested by the data; hence, it was difficult to appraise the effect of irrigation waters. The extremely low salinity status of the soil, relative to the waters, led to the conclusion that very little water had been applied. The salinity and

the alkali levels were of hazardous magnitudes in the non-irrigated profile, but were quite low in the irrigated profile.

The analyses of the profiles of the Ulysses series (site 14) indicated very little change in the salinity and alkali status of the irrigated profile. The soluble salt and sodium levels in both soils were very low. Good quality water had been used for irrigation.

In general, the calcium carbonate determinations indicated native differences in the calcium carbonate content of irrigated and non-irrigated profiles; consequently, the effect of irrigation, in this regard, was difficult to evaluate.

Highly significant correlation coefficients were obtained for the relationship between sodium adsorption ratio of the saturation extract and the exchangeable sodium percentage for the horizons of both irrigated and non-irrigated profiles. Significant correlations also were obtained between the following chemical characteristics of irrigation waters and soils: (1) sodium adsorption ratio of irrigation waters and exchangeable sodium percentage, both for the upper 2 feet and the entire profile; (2) sodium percentage of irrigation water and the per cent sodium in the saturation extract for the entire profile; (3) total soluble cation content of irrigation waters and the total soluble cation content of saturation extract for the entire profile.

The results of this study would indicate that more study is needed in appraising the influence of rainfall on the hazard associated with the use of high salinity waters in sub-humid and semi-arid regions. In many instances the mean salt content in the saturation extract was notably lower than that of the irrigation waters. This would suggest that the soil solution apparently had been diluted or displaced by rain water to a certain extent.

ACKNOWLEDGMENTS

The author wishes to express deep gratitude and sincere appreciation for the wise guidance and encouragement given by his major professor, Dr. Hyde S. Jacobs. Appreciation also is extended to Dr. Roscoe Ellis, Jr. for the advice and suggestions freely given with regard to the chemical analyses.

Special acknowledgment is made to Robert K. Glover and Rodney Harner, Soil Scientists of the U. S. D. A. Soil Conservation Service, for their excellent cooperation in the location of representative soil sampling sites, for their assistance in the soil sampling work and for their descriptions of the profiles. Acknowledgment also goes to the following personnel of the U. S. D. A. Soil Conservation Service for their cooperation and assistance in the location of sampling sites and the soil sampling work: Charles McDee, Soil Scientist; Harold Dickey, Soil Scientist; and Mr. Angell, Soil Scientist.

LITERATURE CITED

- (1) Bower, C. A. and J. O. Goertzen.
Replacement of adsorbed sodium in soils by hydrolysis of calcium carbonates. *Soil Sci. Amer. Proc.* 22:33-35. 1958.
- (2) Doneen, L. D. and D. W. Henderson.
Quality of irrigation waters. *Cal. Agr. Exp. Cal. Agr.* 11:7-8. 1957.
- (3) Eaton, F. M.
Significance of carbonates in irrigation waters. *Soil Sci.* 69:123-133. 1950.
- (4) Pine, L. O., E. J. Williamson, Frank Wierma and C. R. Umback.
Study of the sodium adsorption ratio and residual sodium carbonate concepts of irrigation waters as they affect exchangeable sodium of soil under semi-arid conditions. *Soil Sci. Soc. Amer. Proc.* 23:263-266. 1959.
- (5) Frape, G. S. and T. J. Fudge.
Replacement of calcium in soils by sodium from synthetic irrigation water. *Jour. Amer. Soc. Agron.* 30:789-796. 1938.
- (6) Harper, H. J. and O. E. Stout.
The relation of soil texture to soluble salt accumulation in 29 irrigated soils in Oklahoma. *Ok. Agr. Exp. Sta. Tech. Bul.* T-39. 1950.
- (7) Jackson, M. L.
Soil Chemical analysis. Prentice-Hall, Englewood Cliffs, N. J. p. 88. 1958.
- (8) Kelly, W. P., S. M. Brown and G. F. Liebig.
Chemical effects of saline irrigation water on soils. *Soil Sci.* 49:95-107. 1940.
- (9) Lewis, G. C. and R. L. Juve.
Some effects of irrigation water quality on soil characteristics. *Soil Sci.* 81:125-137. 1956.
- (10) Longenecker, D. E. and P. J. Iyerly.
Chemical characteristics of soils of west Texas as affected by irrigation water quality. *Soil Sci.* 87:207-216. 1959.
- (11) McGeorge, W. T.
A study of lime-induced chlorosis in Arizona orchards. *Ariz. Agr. Exp. Sta. Tech. Bul.* 117. 341-388. 1949.

- (12) McGeorge, W. T.
The salinity problem; Safford experiment farm laboratory studies.
Ariz. Agr. Exp. Tech. Bul. 125:125-155. 1952.
- (13) Scofield, C. S.
Salt balance in irrigated areas. Jour. Agr. Res. 61:17-39. 1940.
- (14) Thorne, D. W. and J. P. Thorne.
Changes in composition of irrigated soil as related to the
quality of irrigation waters. Soil Sci. Soc. Amer. Proc.
18:92-97. 1954.
- (15) United States Salinity Laboratory Staff.
Diagnosis and improvement of saline and alkali soils. U.S.D.A.
Handbook No. 60. 1954.
- (16) Wilcox, L. V.
Classification and use of irrigation waters. U.S.D.A. Circ.
969. 1955.
- (17) Wilcox, L. V., G. Y. Blair and C. A. Bower.
Effect of bicarbonate on the suitability of water for irrigation.
Soil Sci. 77:259-266. 1954.

APPENDIX

IRRIGATION WATER ANALYSES

Table 15. Chemical analyses of irrigation waters.

Site no.	Water Source Analyzed	pH	EC X 10 ⁶	SAR**	Sodium per cent	Possible sodium per cent	Cations—mg./l.				Anions—mg./l.			
							K	Na	Ca	Mg	CO ₃	HCO ₃	Cl	SO ₄
1a	Solomon R. at Holcott	7.6	515***	1.08	23.54	59.76		1.47	2.95	0.73		2.69	0.97	1.41
2a,3a	Solomon R. at Downs	7.8	645***	1.03	24.69	59.92		1.60	3.84	1.04		3.81	0.61	2.02
4a	Well on Gerald Smith farm	8.0	803.2	2.04	35.96	74.54	0.13	3.65	4.24	2.13		5.63	1.92	1.65
5a	Well on Henry Remis farm		1904***	4.00	47.06	74.54		8.96	8.60	1.48		7.02	4.00	7.97
6a	Arkansas R. at Dodge City	7.8	2263***	3.63	41.19	48.98		9.40	8.28	5.15	0.24	3.40	2.00	17.79
	Well on Boyd farm	8.1	723.3	0.87	20.66	35.84	0.13	1.43	3.36	1.98		2.93	1.55	3.10
7a	Arkansas R. at Dodge City	7.8	2283***	3.63	41.19	48.98		9.40	8.28	5.15	0.24	3.40	2.00	17.79
7a*	Well on Wetland farm													
8a	Well on Ralph Tuttle farm	8.2	555.6	1.15	22.18	65.60	0.12	1.64	2.40	1.66		3.32	0.32	2.30

Table 15. (continued)

Site no.	Water Source Analyzed	pH	EC X 10 ⁶ * SAR**per cent	Sodium per cent	Possible Cations—meq./l.				Anions—meq./l.			
					EC	K	Na	Ca	Mg	CO ₃	HCO ₃	Cl SO ₄
9a	Well on Kelly McClure farm	8.3	391.4	0.79	29.17	100.00	0.07	0.89	1.96	0.59	2.91	0.17 0.60
10a	Well on A. B. Sherwood farm	8.3	329.5	0.62	21.21	100.00	0.07	0.70	2.00	0.53	2.91	0.10 1.50
11a	Well on H. F. Waldron farm	8.1	302.6	0.75	26.60	100.00	0.08	0.75	1.46	0.53	2.41	0.12 0.40
12a	Arkansas R. at Dodge City	7.8	2283***	3.63	41.19	48.98		9.40	8.28	5.15	0.24	3.40 2.00 17.29
12a*	Well on L. G. Armstrong farm	8.2	4884	6.50	43.51	47.04	0.38	27.20	16.20	16.70	4.66	7.90 50.80
13a	Well on W. A. Squire farm	8.0	3977	5.80	43.06	46.84	0.29	21.80	14.20	14.30	4.05	4.43 42.00
14a	Well on Parson Bros. farm	8.2	552.5	1.31	32.52	93.01	0.12	1.73	1.60	1.87	3.46	0.32 2.00

Analyses of the Solomon River at Beloit and Downs and the Arkansas River at Dodge City, which were received from the Kansas State Board of Health, represent the average composition for May, June, July and August of 1957 and 1958.

* EC X 10⁶ = electrical conductivity in micromhos per cm.

** SAR = sodium adsorption ratio

*** Electrical conductivity in micromhos per cm. was estimated by the equation: EC X 10⁶ = meq./l. X 10².

Table 16. (continued)

SOIL DETERMINATIONS									
Depth	pH	Soil Saturation ¹ Paste Per Cent	Exchangeable Cations meq./100g. soil			Exchange Capacity meq./100g. soil	Exchangeable Sodium Per Cent		Calcium Carbonate Gypsum Per Cent meq./100g.
			K	Na	Ca	Mg			
Site - 1 a: S ₁ ² , S ₂ ² , Sec. 7; T 7-S, R 7-W; Irrigated 7 years									
0-8	7.7	50.60	1.10	0.41	20.13	1.42			
8-15	7.8	61.20	0.98	1.54	27.31	1.20	1.64	6.30	
15-25	7.8	55.90	0.88	1.19	26.18	1.19	4.62	6.47	
25-31	7.9	40.02	0.54	0.56	16.13	0.82	3.86	6.46	
31-35	7.8	52.33	0.47	0.84	23.56	1.67	3.69	5.56	
35-44	7.8	58.12	0.61	0.86	27.35	1.97	2.85	6.50	
44-48	8.0	44.90	0.92	0.38	19.22	1.35	2.95	6.49	
Weighted mean							1.76	6.46	
							3.15	6.33	
Site - 1 b: S ₁ ² , S ₂ ² , Sec. 12; T 7-S, R 8-W; Non-Irrigated									
0-9	7.2	47.80	0.64	0.05	19.39	0.76	0.22	4.51	
9-17	7.2	55.90						6.41	
17-24	7.6	55.84	0.45	0.10	26.80	1.16	0.33	6.44	
24-30	7.6	49.04	0.84	0.11	22.84	1.07	0.43	6.41	
30-41	7.7	46.60	0.83	0.07	20.18	1.27	0.29	6.45	
41-59	7.7	41.24	0.54	0.04	13.88	0.92	0.31	5.27	
59-66	7.6	47.00	0.77	0.16	18.10	1.53	0.73	6.48	
Weighted mean							0.31	5.90	

Table 17. Chemical analyses for the profiles of an irrigated and a non-irrigated soil in Mitchell County, Kansas.

SATURATION EXTRACT DETERMINATIONS											
Soil - 1WAX						Anions-sec./100% soil					
Depth pH		Cations-sec./100% soil				CO ₃ HCO ₃		Cl SO ₄		Soluble Sodium Adsorption Ratio	
Electrical Conductivity (mhos/cm)		K	Na	Ca	Mg	Total				Percentage	
Site - 2 a: S ₁ H, Sec. 25; T 6-S, R 1-W; Irrigated 18 years.											
0-6	8.0	0.497	0.03	0.02	0.15	0.02	0.22	0.19	0.05	0.03	0.27
6-12	7.8	0.363	0.01	0.05	0.11	0.01	0.18	0.17	0.02	0.02	0.21
12-17	8.1	0.350	0.01	0.11	0.09	0.01	0.22	0.16	0.02	0.03	0.22
17-27	7.8	0.363	0.01	0.12	0.10	0.01	0.24	0.18	0.02	0.04	0.24
27-37	7.7	0.326	0.01	0.09	0.14	0.01	0.25	0.18	0.02	0.05	0.25
37-45	8.1	0.384	0.02	0.06	0.14	0.02	0.24	0.12	0.02	0.08	0.24
45-51	7.5	0.435	0.03	0.06	0.15	0.03	0.27	0.12	0.03	0.13	0.28
51-67	7.5	0.545	0.04	0.06	0.22	0.06	0.38	0.10	0.10	0.24	0.44
Weighted mean							0.27				28.77
Site - 2 b: S ₁ H, Sec. 26; T 6-S, R 10-W; Non-irrigated											
0-6	7.9	0.335	0.02	0.01	0.16	0.01	0.20	0.19	0.04	0.03	0.26
6-12	7.9	0.297	0.01	0.01	0.15		0.17	0.16	0.02	0.02	0.20
12-17	7.7	0.311	0.01	0.01	0.13		0.15	0.15	0.01	0.02	0.18
17-27	7.9	0.384	0.01	0.01	0.18	0.01	0.21	0.15	0.02	0.03	0.20
27-37	7.7	0.356	0.01	0.01	0.16	0.02	0.20	0.15	0.02	0.04	0.21
37-45	7.8	0.355	0.02	0.01	0.14	0.02	0.19	0.13	0.02	0.03	0.18
45-51	7.8	0.341	0.02	0.01	0.14	0.02	0.19	0.12	0.01	0.03	0.16
51-67	7.9	0.497	0.04	0.01	0.16	0.04	0.25	0.19	0.02	0.03	0.24
Weighted mean							0.20				5.26

Table 17. (continued)

SOIL DETERMINATIONS									
Depth	pH	Exchangeable Cations			Exchange Capacity		Exchangeable		Gypsum
Paste	Soil Saturation	K	Na	Ca	Mg	meq./100g. soil	Sodium Per Cent	Calcium Carbonate Per Cent	meq./100g.
Site - 2 a: S ₁ , Sec. 25; T 6-S, R 1-W; Irrigated 18 years									
0-6	7.6	45.92	0.90	0.18	19.98	1.33	0.84	4.22	
6-12	7.7	43.48	0.49	0.28	22.52	0.82	1.39	9.01	
12-17	7.7	43.86	0.49	0.47	22.54	0.82	2.28	8.54	
17-27	7.7	46.78	0.64	0.53	20.03	1.19	2.17	5.03	
27-37	7.6	47.82	0.77	0.36	16.86	1.09	1.40	1.96	
37-45	7.7	47.72	0.86	0.24	21.74	2.66	1.04	4.61	
45-51	7.7	45.70	1.02	0.22	22.35	2.65	0.98	5.40	
51-57	7.8	45.62	1.16	0.19	23.28	3.17	0.92	9.13	
Weighted mean							1.33	6.08	
Site - 2 b: S ₁ , Sec. 26; T 6-S, R 10-W; Non-irrigated									
0-6	7.7	47.76	1.06	0.17	16.09	1.04	0.77	3.03	
6-12	7.7	46.88	0.52	0.17	23.35	0.70	0.83	8.60	
12-17	7.6	44.80	0.49	0.17	22.62	0.70	0.90	9.15	
17-27	7.6	47.06	0.64	0.14	22.57	1.02	0.55	5.88	
27-37	7.6	50.66	0.79	0.14	21.97	1.28	0.51	2.00	
37-45	7.5	46.18	0.78	0.14	18.74	1.88	0.55	1.97	
45-51	7.5	48.12	0.86	0.14	16.74	1.88	0.57	1.64	
51-57	7.6	46.50	0.99	0.14	16.84	2.09	0.63	2.89	
Weighted mean							0.64	3.97	

Table 1B. Chemical analyses for the profiles of an irrigated and a non-irrigated soil in Osborne County, Kansas.

Soil - 1W-X

SATURATION EXTRACT DETERMINATIONS

Depth ft	Electrical Conductivity (micmo/cm)	Cations-meq./100% soil					Anions-meq./100% soil					Soluble Sodium Adsorption Ratio	
		K	Na	Ca	Mg	Total	CO ₃	HCO ₃	Cl	SO ₄	Total		
Site - 3 at W ₂ , SW ₄ , Sec. 28; T 6-S, R 11-W; Irrigated 13 years													
0-6	7.4	0.666	0.03	0.03	0.13	0.04	0.23	0.12	0.15	0.02	0.29	12.86	0.49
6-19	7.5	0.418	0.01	0.04	0.10	0.03	0.18	0.18	0.02	0.03	0.23	24.18	0.85
19-32	7.6	0.352	0.01	0.05	0.07	0.01	0.14	0.13	0.01	0.02	0.16	32.13	1.07
32-40	7.7	0.411	0.02	0.03	0.08	0.02	0.15	0.11	0.02	0.02	0.15	22.59	0.74
40-48	7.7	0.438	0.02	0.02	0.08	0.02	0.14	0.11	0.02	0.04	0.17	16.10	0.51
48-66	7.7	0.505	0.03	0.02	0.03	0.03	0.16	0.11	0.03	0.06	0.20	11.05	0.37
Weighted mean						0.16						19.96	0.67
Site - 3 at W ₂ , SW ₄ , Sec. 29; T 6-S, R 11-W; Non-irrigated													
0-6	7.3	0.325	0.02	0.01	0.06	0.02	0.11	0.07	0.03	0.03	0.13	8.59	0.24
6-19	7.5	0.769	0.01	0.06	0.17	0.04	0.28	0.16	0.09	0.04	0.31	21.91	0.92
19-28	7.7	0.425	0.01	0.02	0.11	0.03	0.17	0.18	0.01	0.03	0.22	10.97	0.34
28-40	7.7	0.396	0.02	0.01	0.09	0.02	0.14	0.12	0.01	0.03	0.16	9.92	0.30
40-48	7.8	0.404	0.02	0.02	0.07	0.03	0.14	0.10	0.02	0.02	0.14	12.75	0.40
48-62	7.5	0.425	0.03	0.02	0.06	0.03	0.14	0.10	0.01	0.03	0.14	13.71	0.44
62-68	8.0	0.462	0.03	0.02	0.06	0.03	0.14	0.11	0.02	0.02	0.15	16.98	0.57
Weighted mean						0.17						13.85	0.48

Table 18. (continued)

SOIL DETERMINATIONS									
Depth	pH	Soil Saturation Paste Per Cent	Exchangeable Cations meq./100g. soil			Exchange Capacity meq./100g. soil	Exchangeable Sodium Per Cent	Calcium Carbonate Per Cent	Gypsum meq./100g.
			K	Na	Ca	Mg			
Site - 3 a: W ₁ , S _W ₁ , Sec. 28; T 6-S, R 11-W; Irrigated 13 years									
0-6	7.0	40.38	1.00	0.17	13.12	2.29			
6-19	7.1	43.68	0.84	0.26	14.65	2.30	0.63	1.37	
19-32	7.2	42.30	0.77	0.25	14.93	2.09	1.23	1.47	
32-40	7.7	40.90	0.96	0.25	19.42	2.61	1.22	1.62	
40-48	7.8	40.08	1.06	0.18	21.17	2.61	1.25	3.11	
48-66	7.9	39.50	1.15	0.16	18.05	3.10	0.92	5.28	
							0.91	4.81	
Weighted mean							1.05	3.10	
Site - 3 b: E ₁ , S _W ₁ , Sec. 29; T 6-S, R 11-W; Non-irrigated									
0-6	6.9	37.00	0.81	0.09	10.69	1.88	0.51	1.24	
6-19	7.3	43.14	0.52	0.12	13.45	1.91	0.54	1.56	
19-28	7.8	42.72	0.67	0.16	14.14	1.92	0.74	1.77	
28-40	7.9	40.16	0.88	0.17	21.41	2.31	0.85	4.69	
40-48	8.0	40.10	1.08	0.21	20.68	2.67	1.07	6.04	
48-62	7.9	38.02	1.20	0.21	19.94	3.00	1.18	5.56	
62-68	8.0	38.58	1.15	0.21	18.44	2.80	1.17	4.86	
Weighted mean							0.86	3.72	

Table 19. (continued)

SOIL DETERMINATIONS									
Depth	pH	Exchangeable Cations			Exchange Capacity		Exchangeable Sodium		Calcium Carbonate
Soil Profile	Saturation Per Cent	X	Na	Ca	meq./100g. soil	meq./100g. soil	Per Cent	Per Cent	Oxygen
Site - 4 a: NE $\frac{1}{2}$, Sec. 1; T 7-S, R 8-W; Irrigated 2 years									
0-4	6.9	39.88	0.98	0.75	11.53	3.66	15.83	3.98	1.41
4-9	6.8	46.90	0.76	1.26	14.66	6.79	21.67	5.81	1.72
9-13	7.0	59.64	0.97	1.48	18.98	6.35	32.17	4.60	2.05
13-25	7.1	60.56	0.98	1.07	19.60	6.32	33.17	3.23	2.32
25-30	7.2	56.78	0.90	1.15	21.38	6.17	32.67	3.52	2.57
30-37	7.5	50.46	0.86	1.25	23.41	7.80	31.08	4.02	3.60
37-55	7.6	50.24	0.97	1.60	20.82	7.80	29.92	5.35	3.11
Weighted mean							4.44		2.62
Site - 4 b: SE $\frac{1}{2}$, Sec. 36; T 6-S, R 8-W; Non-Irrigated									
0-7	6.5	42.10	0.97	0.10	10.94	3.29	20.33	0.49	1.15
7-11	6.7	52.74	0.88	0.18	16.11	7.06	31.50	0.59	1.86
11-24	6.9	59.02	0.98	0.39	19.15	7.44	33.33	1.17	2.18
24-38	7.1	55.50	0.86	0.40	17.05	7.13	31.25	1.28	2.40
38-55	7.2	52.60	0.97	0.65	20.99	7.37	28.83	2.28	3.96
35-53	7.6	49.26	1.08	1.48	20.37	7.31	30.00	4.93	3.39
53-57	7.5	47.78	1.07	2.13	17.86	6.41	30.08	7.08	2.46
Weighted mean							2.63		2.67

Table 20. (continued)

SOIL DETERMINATIONS									
Depth	pH	Saturation	Exchangeable Cations			Exchange	Exchangeable		Gypsum
Paste	Per Cent	Per Cent	K	Na	Ca	mg./100g. soil	Sodium	Calcium	Per Cent meq./100g.
							Per Cent	Carbonate	
Site - 5 a: IM ₂ , Sec. 20; T 7-S, R 6-N: Irrigated 3 years									
0-7	7.4	62.30	1.38	1.29	31.01	3.53	3.37	4.36	
7-14	7.9	67.46	0.91	1.26	30.99	3.96	4.83	7.81	
14-26	7.6	68.56	0.83	1.95	28.84	5.10	5.11	9.18	
26-36	7.6	65.44	0.72	2.42	23.35	4.96	6.69	7.01	15.25
36-46	7.8	61.20	0.53	3.07	20.39	5.35	10.96	9.04	
Weighted mean							6.23	7.65	
Site - 5 b: SM ₂ , Sec. 20; T 7-S, R 6-N: Non-irrigated									
0-7	7.5	60.08	0.92	0.16	32.11	1.03	0.41	5.59	
7-14	7.5	62.76	1.48	0.16	32.10	0.93	0.43	8.48	
14-26	7.4	68.96	0.99	0.18	33.62	1.33	0.44	4.53	
26-36	7.6	67.00	1.04	0.18	30.88	1.53	0.54	3.57	
36-42	7.5	57.14	0.83	0.15	26.02	1.30	0.53	7.16	
42-48	7.5	48.86	0.62	0.14	22.37	1.12	0.57	9.25	
48-66	7.6	45.86	0.51	0.16	20.21	1.36	0.78	5.50	
Weighted mean							0.50	5.84	

Table 21. (continued)

Table 22. Chemical analyses for the profiles of an irrigated soil in Kearney County and an irrigated soil in Finney County, Kansas.

SATURATION EXTRACT DETERMINATIONS										
Soil - irrigated										
Depth pH	Electrical Conductivity (mhos/cm)	Cations-meq./100g. soil			Anions-meq./100g. soil			Soluble Sodium Percentage	Sodium Adsorption Ratio	
		K	Na	Ca	Mg	Total	CO ₃	HCO ₃	Cl	SO ₄ Total
Site - 7 a: S ₁ , Sec. 24; T 23-S, R 34-W, Kearney Co.: Irrigated 52 years										
0-6	8.0	0.215	0.03	0.23	0.11	0.10	0.47	0.30	0.07	0.10
6-16	7.4	3.247	0.03	0.77	0.67	0.30	1.77	0.17	0.06	1.70
16-26	7.3	4.877	0.03	1.36	0.79	0.50	2.68	0.16	0.06	2.57
26-42	7.3	4.308	0.05	1.15	0.78	0.38	2.36	0.08	0.45	1.95
42-58	7.2	4.149	0.09	0.89	0.71	0.33	2.02	0.06	0.73	1.57
Weighted mean						1.90				
Site - 7 a: S ₁ , Sec. 19; T 23-S, R 34-W, Finney Co.: Irrigated 11 years										
0-7	7.6	0.384	0.04	0.04	0.13	0.08	0.29	0.26	0.06	0.06
7-13	7.3	0.718	0.03	0.12	0.15	0.09	0.39	0.26	0.06	0.07
13-25	7.4	1.699	0.05	0.32	0.31	0.19	0.87	0.14	0.33	0.45
25-40	7.4	2.123	0.07	0.40	0.28	0.22	1.07	0.14	0.33	0.67
40-60	7.6	2.453	0.08	0.44	0.46	0.19	1.17	0.11	0.39	0.73
Weighted mean						0.90				

Table 23. (continued)

SOIL DIFFERENTIATIONS									
Depth	pH	Saturation Per Cent	Exchangeable Cations meq./100g. soil	Ca	Mg	Exchange Capacity meq./100g. soil	Exchangeable Sodium Per Cent	Calcium Carbonate Per Cent	Gypsum meq./100g.
Site - 8 at SW $\frac{1}{2}$, Sec. 9; T 30-S, R 37-N; Irrigated 15 years									
0-6	7.8	45.78	1.72	0.26	19.88	4.13	0.99	1.42	
6-16	7.4	51.50	1.43	0.37	17.62	6.21	1.23	1.95	
16-27	7.9	51.30	1.50	0.22	47.31	7.35	0.72	6.92	
27-42	7.9	46.46	0.85	0.49	45.03	7.28	1.88	5.20	
42-58	7.7	43.64	0.85	0.68	40.99	5.69	3.09	3.78	
Weighted mean							1.79	4.14	
Site - 8 at SW $\frac{1}{2}$, Sec. 10; T 30-S, R 37-N; Non-irrigated									
0-5	7.5	31.12	1.84	0.09	19.26	3.97	0.38	1.97	
5-13	7.2	45.06	1.30	0.09	19.01	3.92	0.38	2.28	
13-22	7.7	41.28	0.99	0.11	53.62	5.32	0.42	10.46	
22-34	7.8	41.54	0.99	0.36	51.15	5.95	0.47	10.78	
34-48	7.9	42.46	1.04	0.10	48.66	6.94	0.41	7.32	
48-60	7.9	36.60	0.99	0.32	48.70	6.32	1.56	5.15	
Weighted mean							0.62	6.99	

Table 24. (continued)

SOIL DETERMINATIONS									
Depth	pH	Exchangeable Cations			Exchange Capacity		Exchangeable Sodium		Calcium Carbonate
Soil	Saturation	meq./100g. soil			meq./100g. soil		Per Cent		Per Cent
Paste	Per Cent	K	Na	Ca	Mg				Gypsum
Site - 9 a: M ² , Sec. 25; T 29-S, R 32-W; Irrigated 9 years									
0-5	7.4	47.82	1.74	0.15	18.91	4.86	0.52	0.61	
5-11	7.4	59.62	1.60	0.37	26.39	7.38	0.93	1.57	
11-20	7.7	55.68	1.33	0.54	41.93	7.83	1.43	2.92	
20-37	7.7	50.90	1.37	1.26	39.88	6.50	3.60	2.44	
37-60	7.5	52.34	1.23	1.09	34.17	4.41	3.21	1.67	0.06
Weighted mean									
							2.60	1.75	
Site - 9 b: S ² , Sec. 26; T 29-S, R 32-W; Non-irrigated									
0-5	6.6	43.86	1.72	0.19	15.86	4.92	0.74	0.45	
5-14	7.0	60.80	1.60	0.29	22.71	9.80	0.75	3.96	
14-19	7.7	55.14	1.23	0.40	58.62	9.82	1.24	12.52	
19-36	7.9	50.70	1.21	1.20	58.16	9.95	4.12	12.59	
36-60	7.6	50.76	1.42	1.45	53.35	9.32	5.14	5.11	
Weighted mean									
							3.50	6.43	

Table 26. Chemical analyses for the profiles of an irrigated and a non-irrigated soil in Haskell County, Kansas.

Soil - "Spearville Silty Clay Loam" SATURATION EXTRACT DETERMINATIONS

Depth pH	Electrical Conductivity (mhos/cm)	Cations-meq./100g. soil				Anions-meq./100g. soil				Soluble Sodium Percentage	Sodium Adsorption Ratio
		K	Na	Ca	Mg	Total	CO ₃	HCO ₃	Cl	SO ₄	Total

Site - 11 a: S₁, Sec. 24; T 29-S, R 21-W: Irrigated 10 years

0-7	7.3	0.578	0.03	0.05	0.09	0.66	0.23	0.10	0.11	0.04	0.25	22.55	0.93
7-17	7.4	0.803	0.03	0.12	0.15	0.11	0.41	0.12	0.26	0.07	0.45	30.18	1.47
17-20	7.3	0.640	0.02	0.12	0.09	0.08	0.31	0.19	0.12	0.07	0.38	38.59	1.82
20-27	7.5	0.523	0.02	0.13	0.06	0.05	0.26	0.17	0.04	0.07	0.28	50.79	2.50
27-52	7.5	1.078	0.04	0.31	0.33	0.09	0.77	0.16	0.20	0.53	0.89	40.23	3.05
52-60	7.4	3.378	0.07	0.83	0.56	0.25	1.71	0.11	0.69	0.75	1.75	48.82	5.85
Weighted mean												37.00	2.78

Weighted mean

Site - 11 b: N₁, Sec. 25; T 29-S, R 21-W: Non-irrigated

0-5	6.8	0.839	0.05	0.03	0.13	0.06	0.27	0.14	0.04	0.03	0.21	13.11	0.58
5-15	7.2	0.672	0.03	0.12	0.11	0.08	0.34	0.19	0.06	0.06	0.31	34.07	1.62
15-22	7.6	0.742	0.03	0.19	0.10	0.08	0.40	0.18	0.08	0.11	0.37	49.02	2.79
22-26	7.5	1.107	0.03	0.30	0.11	0.10	0.54	0.18	0.12	0.24	0.54	55.19	4.08
26-50	7.5	4.064	0.08	0.80	0.90	0.39	2.17	0.08	0.44	1.77	2.29	36.76	4.44
50-62	7.3	2.270	0.04	0.49	0.27	0.14	0.94	0.11	0.55	0.38	1.04	51.78	5.00
Weighted mean												39.50	3.53

Weighted mean

Table 26. (continued)

SOIL DETERMINATIONS									
Depth	pH	Saturation	Exchangeable Cations			Exchange Capacity	Exchangeable Sodium		Oxygen
Paste	Per Cent	Per Cent	K	Na	Ca	meq./100g. soil	Per Cent	Per Cent	meq./100g.
Site - 11 a: SE $\frac{1}{2}$, Sec. 24; T 29-S, R 31-W; Irrigated 10 years									
0-7	7.0	42.06	1.47	0.30	13.21	5.04	1.16		
7-17	7.1	55.28	1.92	0.53	22.75	9.07	1.37	1.54	
17-20	7.6	52.14	1.43	0.63	42.20	9.80	1.79	4.46	
20-27	7.8	51.00	1.36	0.75	45.39	9.25	2.25	8.40	
27-52	7.9	50.12	1.51	1.05	44.70	7.59	3.52	7.92	
52-60	7.7	50.22	1.51	1.32	43.15	6.83	4.70	4.44	
Weighted mean							2.81	5.35	
Site - 11 b: NE $\frac{1}{2}$, Sec. 25; T 29-S, R 31-W; Non-irrigated									
0-5	6.4	39.56	1.45	0.15	10.02	3.99	0.66	0.42	
5-15	6.9	54.36	1.62	0.63	23.09	8.42	1.64	2.35	
15-22	7.6	55.10	1.65	0.99	42.02	11.18	2.63	7.65	
22-26	7.7	51.20	1.50	1.10	45.34	9.05	3.48	7.08	0.68
26-50	7.7	49.82	1.45	1.05	45.72	7.01	3.71	2.60	
50-62	7.5	46.52	1.44	1.14	40.77	6.16	4.25		
Weighted mean							3.06	4.12	

Table 27. Chemical analyses for the profiles of two irrigated soils and a non-irrigated soil in Hamilton County, Kansas.

Soil - <u>Western Clay Loam</u> SATURATION EXTRACT DETERMINATIONS													
Depth ft	Electrical Conductivity (mhos/cm)	Cations—mg./100g. soil				Anions—mg./100g. soil				Soluble Sodium Percentage	Sodium Adsorption Ratio		
		K	Na	Ca	Mg	Total	CO ₃	HCO ₃	Cl			SO ₄	
Site - 12 a: SW ₁₄ , Sec. 29, T 23-S, R 42-W; Irrigated 25-50 years													
0-13	8.0	1.736	0.03	0.37	0.13	0.10	0.63	0.14	0.04	0.52	0.70	58.73	5.38
13-23	7.8	5.127	0.06	1.14	0.73	0.49	2.42	0.09	0.18	2.24	2.51	47.16	7.07
23-41	7.6	5.723	0.05	1.11	0.74	0.52	2.42	0.06	0.20	2.40	2.66	44.84	6.77
41-60	7.5	5.458	0.04	0.90	0.67	0.34	1.95	0.09	0.18	2.00	2.27	45.84	6.22
Weighted mean						1.88						6.34	
Site - 12 a: SW ₁₄ , Sec. 35, T 23-S, R 42-W; Irrigated 16 years													
0-10	7.5	1.425	0.03	0.25	0.23	0.09	0.60	0.15	0.11	0.43	0.69	41.94	3.15
10-17	7.3	3.714	0.03	0.41	0.50	0.22	1.56	0.12	0.03	1.45	1.65	51.87	6.66
17-29	7.3	3.556	0.02	0.78	0.41	0.21	1.42	0.09	0.14	1.30	1.53	54.95	7.13
29-41	7.5	3.667	0.02	0.70	0.42	0.18	1.32	0.03	0.15	1.24	1.47	52.60	6.60
41-60	7.4	4.725	0.04	0.83	0.64	0.37	1.88	0.06	0.16	1.70	1.92	44.55	6.33
Weighted mean						1.43						6.05	
Site - 12 b: SW ₁₄ , Sec. 25, T 23-S, R 42-W; Non-irrigated													
0-9	7.5	0.511	0.05	0.01	0.11	0.02	0.19	0.12	0.05	0.04	0.21	6.22	0.23
9-17	7.5	0.433	0.02	0.01	0.09	0.02	0.14	0.15	0.03	0.02	0.20	7.54	0.24
17-29	7.6	0.514	0.02	0.02	0.10	0.04	0.18	0.14	0.04	0.03	0.21	14.07	0.50
29-41	7.7	0.556	0.03	0.09	0.05	0.03	0.20	0.12	0.04	0.03	0.19	48.47	2.48
41-60	7.7	1.656	0.03	0.36	0.66	0.64	0.49	0.11	0.12	0.34	0.57	48.97	5.41
Weighted mean						0.23						3.64	

Table 27. (continued)

[illegible]

Table 22. Chemical analyses for the profiles of an irrigated and a non-irrigated soil in Hamilton County, Kansas.

Soil - Was Animas Clay Loam SATURATION EXTRACT DETERMINATIONS													
Depth pH	Electrical Conductivity (mbos/cm)	Cations-meq./100% soil				Anions-meq./100% soil				Soluble Sodium Percentage	Sodium Adsorption Ratio		
		K	Na	Ca	Mg	Total	CO ₃	HCO ₃	Cl			SO ₄	Total
Site - 13 a: SW _{1/4} , Sec. 30; T 24-S, R 39-W; Irrigated 7 years													
0-10	8.1	0.02	0.15	0.08	0.05	0.30		0.21	0.04	0.06	0.31	49.93	2.85
10-20	7.6	0.02	0.20	0.09	0.07	0.38		0.21	0.04	0.14	0.39	50.45	3.86
20-38	7.8	0.01	0.25	0.06	0.10	0.42		0.12	0.03	0.29	0.44	60.19	4.69
38-55	7.9		0.12	0.02	0.03	0.17		0.08	0.03	0.11	0.22	67.92	4.63
Weighted mean											59.30	4.15	
Site - 13 b: SW _{1/4} , Sec. 29; T 24-S, R 39-W; Non-irrigated													
0-16	7.6	0.06	0.48	0.29	0.14	0.97		0.23	0.24	0.66	1.13	49.32	5.31
16-29	8.0	0.09	2.15	0.13	0.82	3.23		0.24	0.37	2.68	3.29	67.90	15.38
29-47	8.0	0.03	2.01	0.15	0.53	2.72		0.13	0.19	2.61	2.92	73.94	17.09
47-60	8.1		0.08	0.05	0.05	0.18		0.08	0.04	0.11	0.23	45.01	2.46
Weighted mean											61.14	11.13	

Table 22. (continued)

SOIL DETERMINATIONS									
Depth	pH	Soil Saturation	Exchangeable Cations			Exchange Capacity	Exchangeable Sodium		Calcium
Feet		Per Cent	K	Na	Ca	meq./100g. soil	Per Cent	Per Cent	Carbonate
									Gypsum
									meq./100g.
Site - 13 a: SE $\frac{1}{4}$, Sec. 30; T 24-S, R 39-W; Irrigated 7 years									
0-10	7.8	42.34	1.03	0.73	41.57	6.00	2.67		5.98
10-20	7.9	37.40	0.66	0.58	48.06	7.36	3.29		5.69
20-38	8.0	37.12	0.39	0.60	41.59	8.35	4.40		12.06
38-55	8.2	25.00	0.05	0.13	29.47	2.47	6.50		4.23
Weighted mean							4.53		7.38
Site - 13 b: SE $\frac{1}{4}$, Sec. 29; T 24-S, R 39-W; Non-Irrigated									
0-16	7.7	37.52	0.94	0.47	31.03	4.36	2.61		6.08
16-29	8.3	42.68	1.19	2.66	30.19	16.66	15.38		5.88
29-47	8.3	40.62	0.52	1.52	41.00	9.47	11.78		12.73
47-60	8.2	22.24	0.13	0.15	31.77	2.58	4.69		3.07
Weighted mean							8.93		7.77

Table 29. Chemical analyses for the profiles of an irrigated and a non-irrigated soil in Stevens County, Kansas.

Soil - Misses Silt loam														
SATURATION EXTRACT DETERMINATIONS														
Depth pH	Electrical Conductivity (mhos/cm)	Cations-%/100% soil			Anions-%/100% soil			Soluble Sodium Percentage	Sodium Adsorption Ratio					
		K	Na	Ca	Mg	Total	CO ₃					HCO ₃	Cl	SO ₄
Site - 14 a: SM ₂ , Sec. 43, T 31-S, R 37-W: Irrigated 18 years														
0-6	8.1	0.845	0.02	0.05	0.15	0.08	0.30;	0.01	0.11	0.02	0.04	0.24	16.28	0.74
6-14	8.1	0.602	0.02	0.07	0.11	0.04	0.24		0.13	0.03	0.02	0.18	31.10	1.28
14-26	8.1	0.526	0.01	0.08	0.08	0.07	0.24		0.12	0.04	0.03	0.19	34.84	1.43
26-38	8.0	0.534	0.01	0.08	0.07	0.08	0.24		0.11	0.05	0.08	0.24	32.77	1.35
38-60	7.9	0.669	0.01	0.05	0.06	0.07	0.19		0.08	0.03	0.11	0.22	27.64	1.23
Weighted mean													29.43	1.25
Site - 14 b: ME ₂ , Sec. 8; T 31-S, R 37-W: Non-irrigated														
0-10	7.7	0.771	0.04	0.01	0.16	0.05	0.26		0.16	0.18	0.03	0.37	5.43	0.23
10-20	8.1	0.622	0.01	0.03	0.17	0.07	0.28		0.13	0.16	0.03	0.32	11.22	0.42
20-40	8.0	0.514	0.02	0.03	0.10	0.09	0.24		0.11	0.05	0.03	0.19	13.31	0.47
40-60	8.2	0.634	0.02	0.11	0.10	0.03	0.26	0.01	0.16	0.04	0.07	0.28	50.43	3.78
Weighted mean													26.69	1.50

Table 30. Chemical analyses for the profiles of an irrigated soil in Finney County, Kansas.

Soil - "Miss clay loam"												SATURATION EXTRACT DETERMINATIONS			
Depth pH		Electrical Conductivity (mmhos/cm)	Cations-meq./100g. soil				Anions-meq./100g. soil				Soluble Sodium Percentage	Sodium Adsorption Ratio			
			K	Na	Ca	Mg	Total	CO ₃	HCO ₃	Cl			SO ₄	Total	
Site: NE $\frac{1}{2}$, Sec. 31, T 23-S, R 34-N; Irrigated 52 years															
0-11	8.0	0.531	0.02	0.09	0.08	0.08	0.27	0.17	0.06	0.05	0.28	35.41	1.53		
11-22	8.0	0.806	0.02	0.19	0.09	0.08	0.38	0.15	0.09	0.13	0.37	50.20	2.90		
22-40	7.8	1.204	0.02	0.28	0.10	0.09	0.49	0.11	0.09	0.36	0.56	56.63	4.06		
40-50	7.9	1.506	0.02	0.37	0.11	0.09	0.59	0.09	0.09	0.48	0.66	63.02	5.53		
50-60	7.8	1.455	0.01	0.32	0.13	0.07	0.53	0.11	0.07	0.45	0.63	60.14	4.90		
Weighted mean							0.45					53.21	3.77		
SOIL DETERMINATIONS															
Depth	pH	Soil Paste	Saturation Per Cent	Exchangeable Cations meq./100g. soil				Exchange Capacity meq./100g. soil	Exchangeable Sodium Per Cent		Calcium Carbonate Cypsum Per Cent meq./100g.				
				K	Na	Ca	Mg								
Site: Same as above															
0-11	7.7	48.64	1.36	0.56	22.30	9.35	28.00		2.00		4.93				
11-22	7.9	49.30	0.96	0.81	21.66	8.25	28.10		2.89		9.48				
22-40	7.7	47.10	0.91	1.40	23.53	7.44	25.80		5.43		11.76				
40-50	7.8	44.68	0.88	1.66	23.52	7.11	24.30		6.86		10.27				
50-60	7.8	42.94	0.87	1.48	27.37	6.26	24.40		6.07		8.44				
Weighted mean									4.68		9.29				

SOIL PROFILE DESCRIPTIONS

Sites in Mitchell and Osborne Counties

Site -- 1 a

Owner: Gerald Van Pelt

Profile Location: 365' E and 320' S of gate on NW corner of field in SW $\frac{1}{4}$, SW $\frac{1}{4}$, Sec. 7; T 7-S, R 7-W. Mitchell County.

Irrigation: Irrigated 5 years from Solomon River at rate of 25" per year.

Soil Mapping Symbol: 1M4X

Description of Profile:

- 0-8" Very dark grayish brown to dark grayish brown (10YR 3.5/2m.) heavy silt loam with weak fine and medium granular structure, strongly calcareous, upper one inch of horizon fill material from land leveling of very dark brown (10YR 2/2m.) light silty clay loam, grades within one inch to:
- 8-15" Very dark brown (10YR 2/2m.) light silty clay loam with moderate fine and medium granular structure, strongly calcareous, some dark stains in matrix of very dark gray (10YR 3/1), strongly calcareous with a few threads and splotches of lime, grades within two inches to:
- 15-25" Very dark grayish brown (10YR 3/2m.) light silty clay loam with moderate fine and medium granular structure, calcareous with threads of lime more apparent than in horizon above, grades within one inch to:
- 25-31" Grayish brown (10YR 5/2.5m.) very fine sandy loam with weak fine granular structure, strongly calcareous, grades within two inches to:
- 31-35" Very dark grayish brown (10YR 3.5/2) light silty clay loam with moderate fine and medium granular structure, some thin platy structure at contact with lower horizon, strongly calcareous, grades within one inch to:
- 35-44" Very dark grayish brown (10YR 3/2m.) silty clay loam with moderate medium granular structure, peds have overlap tending toward irregular blocky structure, strongly calcareous, grades slowly to:
- 44-48" Dark grayish brown (10YR 4/1.5m.) heavy silt loam with weak fine granular structure stratified with grayish brown (10YR 5/2m.) very fine sandy loam strongly calcareous.

Site - 1 b

Owner: Earl Engelbert

Profile Location: 200' E and 25' S of gate at NE corner of field in
S $\frac{1}{2}$, SE $\frac{1}{4}$, Sec. 12; T 7-S, R 6-W. Mitchell County.

Irrigation: None

Soil Mapping Symbol: 124X

Description of Profile:

- 0-9" Very dark grayish brown (10YR 3/2m.) heavy silt loam with fine granular structure, strongly calcareous, few worm castings, few fine roots, grades within two inches to:
- 9-17" Dark grayish brown (10YR 4/2m.) light silty clay loam with weak medium granular structure, matrix mottled with very dark grayish brown (10YR 3/2m.) worm castings, calcareous, grades within one inch to:
- 17-24" Dark grayish brown (10YR 3/2m.) light silty clay loam with moderate medium granular structure, visible threads of lime, strongly calcareous, grades within one inch to:
- 24-30" Grayish brown (10YR 5/2m.) silt loam with weak fine granular structure, strongly calcareous with visible threads of lime, grades within one inch to:
- 30-41" Very dark grayish brown (10YR 3/2m.) light silty clay loam with moderate fine and medium granular structure, strongly calcareous, one inch strata of silt loam at 36", few roots, grades within one inch to:
- 41-59" Grayish brown (10YR 5/2m.) very fine sandy loam with weak fine granular structure, stratified into one to two inch layers, few one inch layers of silt loam, strongly calcareous, grades to:
- 59-66" Very dark grayish brown (10YR 3/2m.) silt loam with weak fine granular structure, in the first two inches with thin platy structure from two inches down due to striation of layers, lower part of horizon silty clay loam and structure going to lower depths, strongly calcareous.

Site - 2 a

Owner: A. F. Thille

Profile Location: 129' N and 195' E of SW corner N of driveway in SW $\frac{1}{4}$,
Sec. 25; T 6-S, R 10-W, Mitchell County.

Irrigation: Since 1940 from Solomon River, 20" per year.

Soil Mapping Symbol: 1B4X

Description of Profile:

- 0-6" Very dark grayish brown (10YR 3/2m.) silt loam with very fine weak granular structure, structure stronger at bottom of horizon, strongly calcareous, few fine roots, few worm castings, few coarse quartz sand grains, grades within one inch to:
- 6-12" Very dark grayish brown (10YR 3.5/2m.) heavy silt loam with moderate fine granular structure, strongly calcareous, many worm castings, few fine and medium roots, grades within one inch to:
- 12-17" Dark grayish brown (10YR 4/2m.) with worm castings. Very dark grayish brown (10YR 3/2m.) silt loam with weak fine granular structure, few fine and medium roots, strongly calcareous, grades within one inch to:
- 17-27" Very dark grayish brown (10YR 3/2m.) mass with a mottling of dark grayish brown (10YR 4/2m.) heavy silt loam to light clay loam with moderate fine granular structure, strongly calcareous with threads of soft lime, few fine roots, many worm castings, grades within one inch to:
- 27-37" Very dark grayish brown (10YR 3.5/2m.) clay loam with moderate fine granular structure, strongly calcareous with much lime in the form of threads and splotches and covering surfaces of peds, grades within one inch to:
- 37-45" Very dark grayish brown (10YR 3/2m.) heavy silt loam to light clay loam with weak medium granular structure, strongly calcareous with segregated lime in threads and splotches and covering the vertical faces of the soil peds, grades within one inch to:
- 45-51" Dark grayish brown (10YR 4/2m.) silt loam with weak medium subangular blocky structure to weak medium blocky structure, strongly calcareous with segregated lime on faces of peds but with less than in horizon above, few fine and medium roots, grades to:

- 51-67" Dark grayish brown (10YR 4/2m.) silt loam with weak medium granular structure, strongly calcareous with fine threads and small hard concretions of lime, horizon lightens in color with depth.

Site - 2 b

Owner: L. S. Countryman

Profile Location: 75' W and 30' N of the SW corner of field across road from A. F. Thille driveway in SE $\frac{1}{4}$, Sec. 26; T 6-S, R 10-W, Mitchell County.

Irrigation: None

Soil Mapping Symbol: 1M4X

Description of Profile:

- 0-6" Very dark brown (10YR 2.5/2m.) silt loam with weak very fine granular structure which is stronger at the bottom of horizon, strongly calcareous, many fine and medium roots, grades within one inch to:
- 6-12" Very dark grayish brown (10YR 3.5/2m.) heavy silt loam with moderate fine granular structure, strongly calcareous, several fine and medium roots, grades within one inch to:
- 12-17" Dark grayish brown (10YR 4/2m.) silt loam with weak fine and very fine granular structure, contains visible fine sand, worn castings of very dark grayish brown (10YR 3/2m.) worked throughout horizon, few fine roots, strongly calcareous, grades within one inch to:
- 17-27" Dark grayish brown (10YR 4/2m.) heavy silt loam with moderate fine granular structure, strongly calcareous with fine threads of lime through horizon, few fine roots, many worn castings which suggests mottling with very dark grayish brown (10YR 3/2m.), grades within two inches to:
- 27-37" Very dark grayish brown (10YR 3/2m.) with small spots of dark grayish brown (10YR 4/2m.) clay loam with moderate fine and medium granular structure, strongly calcareous with many fine and medium threads and soft splotches of lime, pod faces not covered with lime, grades within one inch to:
- 37-45" Very dark grayish brown (10YR 3.5/2m.) heavy silt loam with weak medium granular structure, strongly calcareous with threads and soft spots of lime, grades to within one inch to:

- 45-51" Very dark grayish brown (10YR 3/2m.) with spots of dark grayish brown (10YR 4/2m.) heavy silt loam with weak medium sub-angular blocky structure, strongly calcareous with fine threads of lime, many worm castings, grades within one inch to:
- 51-67" Very dark grayish brown (10YR 3/2m.) with spots of dark grayish brown (10YR 4/2m.) clay loam with weak medium sub-angular blocky structure, strongly calcareous with threads and splotches of lime, lime covers vertical faces of peds, several worm casts.

Site - 3 a

Owner: Warren Carey

Profile Location: 430' S and 150' E of NW corner of field in W $\frac{1}{2}$, SW $\frac{1}{4}$,
Sec. 28; T 6-S, R 11-W, Osborne County.

Irrigation: Since 1945 from Solomon River, 6-8" per year.

Soil Mapping Symbol: 1M4X

Description of Profile:

- 0-6" Very dark grayish brown (10YR 3/2m.) loam with weak fine granular structure, many fine and medium roots, few worm casts, noncalcareous, compaction in lower 3 inches from tillage, grades within one inch to:
- 6-19" Very dark grayish brown (10YR 2.5/2m.) clay loam with moderate fine and medium granular structure, noncalcareous, many worm castings, many fine and medium roots, grades within 2 inches to:
- 19-32" Very dark grayish brown to dark grayish brown (10YR 3.5/2m.) silt loam with weak medium granular structure, noncalcareous, few worm castings, few fine roots, grades shortly to:
- 32-40" Dark grayish brown (10YR 4/2m.) silt loam with weak medium subangular blocky structure, strongly calcareous with fine threads of segregated lime, few fine roots, grades within 2 inches to:
- 40-48" Dark grayish brown to grayish brown (10YR 4.5/2m.) light silt loam with weak medium subangular blocky structure, many fine and medium threads and splotches of segregated lime, maximum lime accumulation horizon, few very small concretions, grades within one inch to:
- 48-66" Dark grayish brown to grayish brown (10YR 4.5/2m.) very fine sandy loam with very weak coarse prismatic structure, appears structureless, strongly calcareous with a few very fine threads of segregated lime.

Site - 3 b

Owner: E. Richardson

Profile Location: 135° E and 240° S from driveway into farmstead in E $\frac{1}{2}$,
SE $\frac{1}{4}$, Sec. 29; T 6-S, R 11-W. Osborne County.

Irrigation: None

Soil Mapping Symbol: 1M4X

Description of Profile:

- 0-6" Very dark grayish brown (10YR 3/2m.) loam with weak very fine granular structure, noncalcareous, many fine and medium roots, few worm castings, grades within one inch to;
- 6-19" Very dark brown to very dark grayish brown (10YR 2.5/2m.) clay loam with moderate fine and medium granular structure, noncalcareous, many worm castings, many fine and medium roots, grades within two inches to;
- 19-28" Very dark grayish brown (10YR 3/2m.) silt loam with weak medium granular structure, noncalcareous, few worm castings, few fine roots, grades shortly to;
- 28-40" Very dark grayish brown to dark grayish brown (10YR 3.5/2m.) silt loam with weak medium subangular blocky structure, strongly calcareous with many fine threads of segregated lime, grades within two inches to;
- 40-48" Dark grayish brown (10YR 4/2m.) silt loam with weak medium subangular blocky structure, strongly calcareous with many splotches and threads or mycelia of segregated lime, grades within one inch to;
- 48-62" Dark grayish brown (10YR 4/2m.) silt loam with very weak coarse prismatic structure, strongly calcareous with many very fine mycelia of segregated lime, grades within one inch to;
- 62-68" Dark grayish brown to grayish brown (10YR 4.5/2m.) very fine sandy loam with very weak coarse prismatic structure, strongly calcareous with vertical faces of peds coated with lime. Material continues a few to many feet thick.

Site - 4 a

Owner: Gerald Smith

Profile Location: 1067' W and 50' S of the NE corner of NE $\frac{1}{4}$, Sec. 1;
T 7-S, R 8-W, Mitchell County.

Irrigation: 2 years by well, 18" per year.

Soil Mapping Symbol: 1M34D

Description of Profile:

- | | | |
|------|--------|---|
| Alp | 0-4" | Very dark brown (10YR 2/2m.), light silty clay loam with weak fine granular structure, disturbed by cultivation, few fine roots, few worm castings, noncalcareous, grades within one inch to: |
| A1 | 4-9" | Very dark brown (10YR 2/2m.) silty clay loam with moderate medium and fine granular structure, few fine roots, noncalcareous, few worm casts, upper two inches of horizon compressed, grades within two inches to: |
| A3 | 9-13" | Very dark brown to very dark grayish brown (10YR 2.5/2m.) silty clay loam with moderate medium granular structure tending toward moderate fine subangular blocky structure, noncalcareous, few fine roots, grades within one inch to: |
| B2 | 13-25" | Very dark grayish brown to dark grayish brown (10YR 3.5/2m.) heavy silty clay loam with moderate medium subangular blocky structure, noncalcareous, few fine roots, thin strong continuous clay skins, grades within one inch to: |
| B3 | 25-30" | Dark grayish brown (10YR 4/2m.) heavy silty clay loam with moderate medium angular blocky structure, noncalcareous, thin nearly continuous clay skins, grades within one inch to: |
| B3ca | 30-37" | Dark grayish brown (10YR 4/2m.) silty clay loam with weak coarse prismatic structure breaking to weak medium angular blocky structure. Strongly calcareous with many threads of lime and soft to hard lime concretions, few roots, grades within two inches to: |

- Cca 37-55" Dark grayish brown (10YR 4/2m.) light silty clay loam with weak medium subangular blocky structure, strongly calcareous with threads of lime and a few hard lime concretions, few fine roots, grades to:
- C 55-68" Dark grayish brown (10YR 4/2m.) light silty clay loam with weak coarse prismatic structure, strongly calcareous with a few hard concretions, material continues few to many feet thick.

Site - 4 b

Owner: Charles Vetter

Profile Location: 1256' W and 150' N of the SW corner of SE $\frac{1}{4}$, Sec. 36;
T 6-S, R 8-W, Mitchell County.

Irrigation: None

Soil Mapping Symbol: 1M34D

Description of Profile:

- Alp 0-4" Very dark brown (10YR 2/2m.) light silty clay loam with fine and very fine weak granular structure disturbed by cultivation, compression in lower part of horizon, few fine roots, noncalcareous, grades within one inch to:
- Al 4-8" Very dark brown (10YR 2/2m.) light silty clay loam with moderate fine and medium granular structure, few fine and medium roots, noncalcareous, grades within one inch to:
- A3 8-11" Very dark brown to very dark grayish brown (10YR 2.5/2m.) silty clay loam with moderate medium subangular blocky structure breaking to moderate medium granular structure, noncalcareous, few fine roots, grades within one inch to:
- B2 11-25" Very dark grayish brown to dark grayish brown (10YR 3.5/2m.) heavy silty clay loam with moderate medium subangular blocky structure with strong thin continuous clay skins, few roots, noncalcareous, grades within one inch to:
- B3 25-28" Dark grayish brown (10YR 4/2m.) silty clay loam with moderate fine and medium subangular blocky structure, few fine roots, noncalcareous, grades to:

- B3ca 20-35" Dark grayish brown to dark brown (10YR 4/2.5m.) light silty clay loam with weak medium subangular blocky structure, calcareous with few small concretions of lime in upper part of horizon and threads and soft spots throughout horizon. Larger concretions in lower part of horizon, grades to:
- Gca 35-50" Grayish brown to brown (10YR 5/2.5m.) light silty clay loam with weak coarse prismatic structure, few hard concretions $\frac{1}{8}$ inch in diameter, few very fine roots, grades to:
- C 50-67" Grayish brown to brown (10YR 5/2.5m.) light silty clay loam with weak coarse prismatic structure, calcareous with a few lime threads and spots lessening with depth.

Site - 5 a

Owner: Henry Remus

Profile Location: 249' N and 33' W of SE corner of NW $\frac{1}{4}$, Sec. 20; T 7-S,
R 6-W. Mitchell County.

Irrigation: 3 years by well, 20" per year.

Soil Mapping Symbol: 1HLX

Description of Profile:

- 0-7" Black (10YR 2/1m.) heavy silty clay loam with moderate very fine granular structure in upper 3 inches, lower 4 inches of horizon compacted, very hard even when moist, calcareous, few fine roots mostly in horizontal position above compacted layer, grades within one inch to:
- 7-14" Black (10YR 2/1m.) silty clay with moderate fine and medium irregular blocky, overlap 30-40%, strongly calcareous with a few fine threads of lime, few fine roots, grades within one inch to:
- 14-26" Very dark gray (10YR 3/1m.) clay with moderate medium sub-angular blocky structure, strongly calcareous with soft spots of lime or calcareous material, soft concretions $\frac{1}{2}$ to $\frac{3}{4}$ inch in diameter, few fine roots, strong continuous clayskins, grades slowly to:
- 26-36" Very dark gray (10YR 3.5/1.) clay with moderate medium sub-angular blocky structure, not as strong structure as horizon above, strongly calcareous with large spots and soft concretions of lime - a few concretions $\frac{1}{2}$ inch in diameter, few very fine roots, strong continuous clayskins, grades within two inches to:
- 36-46" Dark gray (10YR 4/1m.) silty clay with weak medium sub-angular blocky structure, strongly calcareous with many hard $\frac{1}{2}$ to $\frac{3}{4}$ inch concretions slightly mottled (3%), very few fine rootlets, grades within two inches to:
- 46-59" Dark gray to dark grayish brown (10YR 4/1.5m.) silty clay loam with weak medium and coarse subangular blocky structure, mottling 3% of dark yellowish brown (7.5YR 4/4), grades within one inch to:

- 59-63" Dark gray to dark grayish brown (10YR 4/1.5m.) clay loam with weak coarse prismatic to weak medium subangular blocky, strongly calcareous with few fine threads of lime, grades slowly to:
- 63-67" Dark gray to dark grayish brown (10YR 4/1.5m.) silty clay with moderate medium angular blocky structure, strongly calcareous with threads of soft lime and a few hard concretions $\frac{1}{2}$ inch in diameter.

Site - 5 b

Owner: Henry Rums

Profile Location: 74' S and 195' W of NW corner of SW $\frac{1}{4}$, SE $\frac{1}{4}$, Sec. 20;
T 7-3, R 6-W, Mitchell County.

Irrigation: None

Soil Mapping Symbol: MLXI

Description of Profile:

- 0-3" Very dark gray (10YR 3/lm.) heavy silty clay loam with very fine granular structure, calcareous, few fine roots, grades to:
- 3-7" Very dark gray (10YR 3/lm.) heavy silty clay loam, very compact from tillage implements, strongly calcareous, few fine roots, grades within one inch to:
- 7-14" Very dark gray (10YR 3/lm.) clay with moderate fine and medium irregular blocky structure with overlap of 30 to 40% horizontally, strongly calcareous with a few very fine concretions, few fine roots, discontinuous clayskins, grades within one inch to:
- 14-26" Black (10YR 2/lm.) clay with moderate fine and medium subangular blocky structure, fine structure tends to overlap horizontally, strongly calcareous, strong continuous clayskins, few fine roots, grades within one inch to:
- 26-36" Very dark gray to very dark grayish brown (10YR 3.5/lm.) clay with moderate medium subangular blocky structure, not quite as strong as the horizon above, strongly calcareous with a few soft lime concretions, strong continuous clayskins, grades to:
- 36-42" Dark gray (10YR 4/lm.) silty clay with weak medium subangular blocky structure, strongly calcareous, contain more lime threads and soft to hard concretions, weak discontinuous clayskins, some mottling (3%), grades within one inch to:

- 42-48" Dark gray (10YR 4/1m.) clay loam with very weak coarse prismatic structure, strongly calcareous with many soft spots and small concretions, mottling 3% of dark brown color (7.5YR 3/2m.), grades shortly to:
- 48-58" Grayish brown (10YR 5/2m.) silt loam with weak coarse prismatic structure, strongly calcareous.

Sites in Finney, Grant and Kearny Counties

Site - 6 a

Owner: Boyd

Profile Location: About 792' W and about 175' N of SE corner of SE $\frac{1}{4}$ of Sec. 18; T 23-S, R 34-W. Finney Co.

Irrigation: From Amazon ditch (directly from Arkansas River) for 52 years, plus irrigation by well for more than 3 years prior to 1958.

Soil Type: "Richfield Clay Loam"

Description of Profile:

Ap	0-9"	Dark grayish brown (10YR 4/2; 3/2m.) silty clay loam, weak very fine granular, slightly hard, friable, calcareous, abrupt smooth boundary.
B ₂	9-15"	Dark grayish brown (10YR 4/2; 3/2m.) silty clay loam, compound moderate fine granular and moderate medium subangular blocky, hard, friable, clayskins apparent, noncalcareous, clear smooth boundary.
B ₂ ca	15-25"	Grayish brown (10YR 5/2; 4/2m.) silty clay loam, moderate, medium subangular blocky, slightly hard, friable, clayskins apparent, calcareous, gradual smooth boundary.
Cca	25-47"	Pale brown (10YR 6/3; 5/3m.) heavy silt loam, weak medium subangular blocky, slightly hard, friable, calcareous, streaked with lime, grades to:
C	47-62"	Very pale brown (10YR 7/3; 6/3m.) heavy silt loam, massive, slightly hard, friable, calcareous.

Site - 6 b

Owner: Garden City Company

Profile Location: 240' S and about 140' W of NE corner of NW $\frac{1}{4}$ of Sec.
20; T 23-S, R 34-W. Finney Co.

Irrigation: None

Soil Type: "Richfield Silt Loam"

Description of Profile:

- | | | |
|-------------------|--------|--|
| Ap | 0-5" | Grayish brown (10YR 5/2; 3/2m.) silt loam, weak very fine granular, slightly hard, friable, abrupt smooth boundary. |
| B ₂ | 5-12" | Dark grayish brown (10YR 4/2; 3/2m.) silty clay loam, moderate very fine subangular blocky, hard, firm, weak clay skins, noncalcareous, gradual smooth boundary. |
| B ₃ Ca | 12-21" | Grayish brown (10YR 5/2; 4/2m.) light silty clay loam, weak fine subangular blocky, slightly hard, friable, weak clay skins, calcareous, grades to: |
| Cca | 21-40" | Very pale brown (10YR 7/3; 5/3m.) heavy silt loam, weak medium subangular blocky, slightly hard, friable, calcareous streaked with lime, grades to: |
| C | 40-60" | Very pale brown (10YR 7/3; 5/3m.) silt loam, massive, slightly hard, friable, calcareous. |

Site - 7 a

Owner: Garden City Company

Profile Location: About 1716' W and about 75' N of SE corner of SE $\frac{1}{4}$ of Sec. 24; T 23-S, R 35-W. Kearny Co.

Irrigation: From Amazon ditch (directly from Arkansas River) for 52 years.

Soil Type: "Richfield Clay"

Description of Profile:

- | | | |
|------------------|--------|--|
| Ap | 0-6" | Grayish brown (10YR 5/2; 3/2m.) silty clay, moderate very fine irregular blocky, very hard, firm, calcareous, abrupt smooth boundary. |
| | 6-16" | Dark grayish brown (10YR 4/2; 2/2m.) silty clay loam, moderate medium subangular blocky, hard, firm, calcareous, gradual smooth boundary. |
| B ₂₂ | 16-26" | Dark grayish brown (10YR 4/2; 3/2m.) silty clay loam, moderate medium subangular blocky, hard, firm, non-calcareous, gradual smooth boundary to: |
| B _{3ca} | 26-42" | Pale brown (10YR 6/3; 4/3m.) heavy silt loam, weak medium subangular blocky, slightly hard, friable, calcareous, few soft lime concretions, grades to: |
| C | 42-58" | Very pale brown (10YR 7/3; 5/3m.) silt loam, massive, slightly hard, friable, calcareous. |

Site - 7 a'

Owner: Weiland

Profile Location: About 924' S and about 325' W of NE corner of Sec. 19;
T 23-S, R 34-W, Finney Co.

Irrigation: By well for 11 years.

Soil Type: "Richfield Clay Loam"

Description of Profile:

- | | | |
|----------------|--------|---|
| Ap | 0-7" | Dark grayish brown (10YR 4/2; 3/2m.) silty clay loam, compound weak fine granular and moderate subangular blocky, slightly hard, friable, few worm castings, some platyness in lower part due to compaction, noncalcareous, abrupt smooth boundary. |
| B ₂ | 7-13" | Dark grayish brown (10YR 4/2; 3/2m.) heavy silty clay loam, strong very fine and medium subangular blocky, hard, firm, moderate clayskins, noncalcareous, grades to: |
| | 13-25" | Gray (10YR 5/1; 3/1m.) light silty clay loam, moderate medium subangular blocky, slightly hard, friable, calcareous, few soft lime concretions, grades to: |
| | 25-40" | Gray (10YR 6/1; 4/1m.) light silty clay loam, moderate fine and medium subangular blocky, slightly hard, friable, calcareous, streaked with lime, grades to: |
| | 40-60" | Light gray (10YR 7/2; 5/2m.) light silty clay loam, massive, slightly hard, friable, weakly calcareous. |

Site - 8 a

Owner: Ralph Tuttle

Profile Location: About 1320' N and 100' W of SE corner of Sec. 9; T 30-S,
R 37-W, Grant County.

Irrigation: By well for 15 years.

Soil Mapping Unit: Richfield Silt Loam

Description of Profile:

- 0-6" Grayish brown (10YR 5/2, 3/2m.), silt loam, weak medium to fine granular, few root hairs, several worn castings, slightly hard, boundary clear.
- 6-16" Brown (10YR 5/3, 3/3m.), silty clay loam, moderate medium to fine subangular blocky, some moderate medium to fine granular, few root hairs, few worn castings, few thin clay films, hard, boundary gradual.
- 16-27" Pale brown (10YR 6/3, 5/3m.), calcareous silty clay loam, moderate medium to fine subangular blocky, with some moderate medium to fine granular, few thin clay films, few root hairs, few worn castings, very hard, boundary gradual.
- 27-42" Light brownish gray (10YR 6/2, 4/2m.), calcareous silty clay loam, moderate medium to fine subangular blocky, with some granular, few thin clay films, few root hairs, few worn casts, very hard, about 2% soft lime concretions, boundary gradual.
- 42-60" Light brownish gray (10YR 6/2, 4/2m.), calcareous silty clay loam, weak to moderate subangular blocky porous, few worn casts, hard, streaks of free lime.

Site - 8 b

Owner: R. Klehm

Profile Location: About 1320' N and 150' E of SW corner of Sec. 10; T 30-S,
R 37-W, Grant County.

Irrigation: None

Soil Mapping Unit: Richfield Silt Loam

Description of Profile:

- 0-5" Grayish brown (10YR 5/2, 4/1m.), calcareous silt loam or silty clay loam, moderate medium to fine granular, few root hairs, some worm castings, slightly hard to hard, boundary clear.
- 5-13" Light brownish gray (10YR 6/2, 4/2m.), silty clay loam, moderate medium to fine subangular blocky and some moderate medium to fine granular structure, many worm castings, few root hairs, hard, boundary gradual.
- 13-22" Light brownish gray (10YR 6/2, 4/2m.), calcareous silty clay loam, moderate medium to fine granular and some moderate medium to fine subangular blocky, porous, many worm castings, hard, boundary gradual.
- 22-34" Pale brown (10YR 6/3, 5/3m.), calcareous silty clay loam, weak medium to fine granular, some weak subangular blocky, porous, few worm castings, slightly hard, 1 to 2% soft lime concretions, boundary gradual.
- 34-48" Pale brown (10YR 6/3, 5/3m.), calcareous silty clay loam, weak medium to fine granular, porous, few worm castings, soft to slightly hard, about 1% soft lime concretions, boundary gradual.
- 48-60" Light yellowish brown (10YR 6/4, 5/4m.), calcareous clay loam, weak medium to fine granular, porous, few worm castings, slightly hard, streaks of free lime.

Sites in Naskell County

Site - 9 a

Owner: Kelly McClure

Profile Location: About 1524' S and about 140' E of junction of Highway 56 and graded road in NW $\frac{1}{4}$ of Sec. 25; T 29-S, R 32-W.

Irrigation: By well since 1949.

Soil Type: "Spearville Silty Clay Loam"

Description of Profile:

Ap	0-5"	Dark grayish brown (10YR 4/2; 3/2m.) silty clay loam, weakly granular, hard, friable, noncalcareous, abrupt smooth boundary.
B ₂₂	5-11"	Dark grayish brown (10YR 4/2; 3/2m.) silty clay, weak fine prismatic breaking to moderate very fine irregular blocky, very hard, very firm, clayskins apparent and continuous, noncalcareous, clear smooth boundary.
B _{2c2}	11-20"	Dark grayish brown (10YR 4/2; 3/2m.) silty clay loam, moderate fine irregular blocky, very hard, very firm, clayskins apparent and continuous, considerable horizontal cleavage, calcareous, grades to:
	20-37"	Grayish brown (10YR 5/2; 4/2m.) silty clay loam, weak very fine subangular blocky, hard, friable, patchy clayskins, calcareous, threads of lime, grades to:
	37-60"	Pale brown (10YR 6/3; 4/3m.) silty clay loam, massive, hard, friable, calcareous, threads of lime.

Site - 9 b

Owner: Kelly McClure

Profile Location: About 137' N and about 300' W of junction of Highway 56 and graded road in SE $\frac{1}{4}$ of Sec. 26; T 29-S, R 32-W.

Irrigation: None

Soil Type: "Spearville Silty Clay Loam"

Description of Profile:

Ap	0-5"	Dark grayish brown (10YR 4/2; 3/2m.) silty clay loam, weakly granular, hard, friable, noncalcareous, abrupt smooth boundary.
B ₂₂	5-14"	Dark grayish brown (10YR 4/2; 3/2m.) silty clay, weak fine prismatic breaking to moderate very fine irregular blocky, very hard, very firm, clayskins apparent and continuous, noncalcareous, clear smooth boundary.
B _{2ca}	14-19"	Grayish brown (10YR 5/2; 4/2m.) silty clay, weak fine subangular blocky, hard, firm, weak patchy clayskins, calcareous, lime concretions and threads, worm castings, grades to:
Cca ₁	19-36"	Pale brown (10YR 6/3; 5/3m.) light silty clay loam, massive, hard, friable, porous, few worm castings, calcareous, lime concretions and threads.
Cca ₂	36-60"	Same as above but sub-divided for sampling purposes.

Site - 10 a

Owner: A. B. Sherwood

Profile Location: About 237' S and about 200' W of NE corner of NE $\frac{1}{4}$ of Sec. 19; T 29-S, R 31-W.

Irrigation: By well 5 out of the 9 years since 1949.

Soil Type: "Spearville Silty Clay Loam"

Description of Profile:

Ap	0-7"	Dark grayish brown (10YR 4/2; 3/2m.) silty clay loam, weakly granular, hard, friable, noncalcareous, abrupt smooth boundary.
B ₂₂	7-13"	Dark grayish brown (10YR 4/2; 3/2m.) silty clay, moderate very fine irregular blocky, very hard, very firm, clayskins apparent and continuous, noncalcareous, clear smooth boundary.
B _{2ca}	13-17"	Grayish brown (10YR 4.5/2; 3.5/2m.) heavy silty clay loam, moderate fine angular blocky, very hard, very firm, discontinuous clayskins, calcareous, clear smooth boundary.
B _{3ca}	17-25"	Brown (10YR 5/2.5; 4/2m.) silty clay loam, weak medium subangular blocky, hard, firm, calcareous, line threads, grades to:
	25-42"	Grayish brown (10YR 5/2; 3.5/2m.) heavy silty clay loam, weak very fine subangular blocky, hard, firm, calcareous, line threads, grades to:
	42-62"	Pale brown (10YR 6/3; 5/3m.) silty clay loam, massive, hard, firm, porous, calcareous, line threads.

Site - 10 b

Owner: A. B. Sherwood

Profile Location: About 924' E and about 175' N of SW corner of SW $\frac{1}{4}$ of Sec. 17; T 29-S, R 31-W.

Irrigation: None

Soil Type: "Spearville Silty Clay Loam"

Description of Profile:

A _{1p}	0-4"	Dark grayish brown (10YR 4/2; 3/2m.) light silty clay loam, weakly granular, hard, friable noncalcareous, abrupt smooth boundary.
A ₁	4-7"	Dark grayish brown (10YR 4/2; 3/2m.) light silty clay loam, moderate fine granular, hard, friable, non-calcareous, clear smooth boundary.
B ₂₂	7-15"	Dark grayish brown (10YR 4/2; 3/2m.) light silty clay, moderate very fine irregular blocky, very hard, very firm, clayedins apparent and continuous, noncalcareous, clear smooth boundary.
B _{3ca}	15-27"	Light brownish gray (10YR 6/2; 5/2m.) silty clay loam, weak very fine subangular blocky, hard, firm, weak patchy clayedins, few worm castings, calcareous, lime concretions, grades to:
Cea ₁	27-36"	Very pale brown (10YR 7/3; 5/3m.) light silty clay loam, massive, hard, friable, porous, calcareous, lime threads, grades to:
Cea ₂	38-58"	Light brown (7.5YR 6/4; 5/1m.) heavy silt loam, massive, hard, friable, porous, calcareous, lime threads.

Site - 11 a

Owner: Waldron

Profile Location: About 792' W and about 60' N of SE corner of Sec. 24;
T 29-S, R 31-W.

Irrigation: By well since 1948.

Soil Type: "Spearville Silty Clay Loam"

Description of Profile:

Ap	0-7"	Dark grayish brown (10YR 4.5/3; 3/3m.) light silty clay loam, weakly granular, hard, firm, noncalcareous, abrupt smooth boundary.
*B ₂₁	7-12"	Dark brown (10YR 4/3; 3/3m.) silty clay, moderate fine prismatic breaking to moderate very fine irregular blocky, very hard, very firm, clayskins apparent and continuous, noncalcareous, clear smooth boundary.
*B ₂₂	12-17"	Dark brown (10YR 4/3; 3/3m.) silty clay, moderate very fine irregular blocky, very hard, very firm, distinct horizontal cleavage, clayskins apparent and continuous, noncalcareous, clear smooth boundary.
B _{2ca}	17-20"	Brown (10YR 5/3; 4/3m.) silty clay, moderate very fine irregular blocky, very hard, very firm, clayskins not as apparent, calcareous, lime concretions, clear smooth boundary.
B _{3ca}	20-27"	Pale brown (10YR 6/3; 4.5/3m.) silty clay loam, weak fine subangular blocky, hard, firm, patchy clayskins, worm castings, calcareous, lime concretions and threads, grades to:
Cca ₁	27-52"	Pale brown (10YR 6/3; 4.5/3m.) light silty clay loam, massive, hard, friable, porous, calcareous, threads of lime, few worm castings.
Cca ₂	52-62"	Same as above but sub-divided for sampling purposes.

*The B₂₁ and B₂₂ horizons were sampled together as one sample.

Site - 11 b

Owner: Waldron

Profile Location: About 792' W and about 72' S of NE corner of Sec. 25;
T 29-S, R 31-W.

Irrigation: None

Soil Type: "Spearville Silty Clay Loam"

Description of Profile:

Ap	0-5"	Brown (10YR 5/3; 3/3m.) light silty clay loam, weak subangular blocky, hard, firm, noncalcareous, abrupt smooth boundary.
*B ₂₁	5-10"	Dark brown (10YR 4/3; 3/3m.) light silty clay, moderate fine prismatic breaking to moderate very fine irregular blocky, very hard, very firm, clayskins apparent and continuous, noncalcareous, clear smooth boundary.
*B ₂₂	10-15"	Dark brown (10YR 4/3; 3/3m.) light silty clay, moderate very fine irregular blocky, very hard, very firm, clayskins apparent and continuous, noncalcareous, clear smooth boundary.
B _{2ca}	15-22"	Grayish brown (10YR 5.5/3; 4/3m.) light silty clay, weak very fine subangular blocky, very hard, firm, continuous clayskins, calcareous, lime concretions, clear smooth boundary.
B _{3ca}	22-26"	Pale brown (10YR 6/3; 4.5/3m.) silty clay loam, weak fine subangular blocky, hard, firm, patchy clayskins, calcareous, lime concretions, grades to:
Cca ₁	26-50"	Very pale brown (10YR 7/4; 5/4m.) light silty clay loam, massive, hard, firm, worm castings, porous, calcareous, threads of lime, grades to:
Cca ₂	50-60"	Same as above except for color which is pale brown (10YR 6/3; 4/3m.)

*The B₂₁ and B₂₂ horizons were sampled together as one sample.

Sites in Hamilton County

Site - 12 a

Owner: Paul Wagner

Profile Location: 200' E and 660' S of NW corner of NW $\frac{1}{4}$ of Sec. 29;
T 23-S, R 42-W.

Irrigation: 25-50 years from Arkansas River. At times, supply canal
picked up drainage waters from Colorado irrigation systems.

Soil Type: "Syracuse Clay Loam"

Description of Profile:

- | | |
|--------|---|
| 0-13" | Grayish brown (10YR 4.5/2; 3.5/2m.) clay loam, moderate medium granular, friable, slightly hard, weakly calcareous, few worm castings in lower part, grades to: |
| 13-23" | Pale brown (10YR 6/2.5; 4/2m.) clay loam, moderate fine granular, friable, slightly hard, calcareous, few worm castings, more than above, colors are intermediate and mixed, grades to: |
| 23-41" | Pale brown (10YR 6/3; 4/2m.) heavy loam, thin strata of sandy loam occurs, massive porous, friable, slightly hard, few small nests and seams of fine white crystals, calcareous, grades to: |
| 41-62" | Pale brown (10YR 6/3; 5/3m.) loam, massive porous, very friable, soft, calcareous, very few small nests and seams of fine white crystals, less than above. |

Site - 12 a¹

Owner: L. G. Armstrong

Profile Location: Center of NE $\frac{1}{4}$ of Sec. 35; T 23-S, R 42-W.

Irrigation: By well since 1942.

Soil Type: Syracuse Clay Loam"

Description of Profile:

- | | |
|--------|--|
| 0-10" | Grayish brown (10YR 4.5/2; 3.5/2m.) light clay loam, weak granular, friable, slightly hard, calcareous, grades to: |
| 10-17" | Grayish brown (10YR 5/2; 4/2m.) light clay loam, otherwise similar to above horizon, worm castings common, grades to: |
| 17-29" | Brown (10YR 5.5/2.5; 4/2m.) heavy loam, massive porous, very friable, soft, strongly calcareous, grades to: |
| 29-41" | Pale brown (10YR 6/2.5; 4/2m.) heavy loam, massive, porous, very friable, soft, calcareous, grades to: |
| 41-62" | Pale brown (10YR 6.5/3; 5/3m.) slightly stratified loam and light clay loam (average loam, massive, porous, very friable, soft, calcareous.) |

Site - 12 b

Owner: Baldwin

Profile Location: 1650' W and 200' N of SE corner of Sec. 25; T 23-S, R 42-W.

Irrigation: None

Soil Type: "Syracuse Clay Loam"

Description of Profile:

- 0-9" Dark grayish brown (10YR 4/2; 3/2m.) light clay loam, moderate fine granular, friable, slightly hard, about 2" recently deposited soil in surface, noncalcareous to about 6", calcareous below, worm castings numerous, grades to:
- 9-17" Grayish brown (10YR 5/2; 4/2m.) light clay loam, weakly granular, friable, slightly hard, calcareous, worm castings numerous, grades to:
- 17-29" Pale brown (10YR 6/2.5; 4/2m.) heavy loam, massive porous, very friable, soft, strongly calcareous with some few small soft concretions, film, streaks of lime, few worm castings, grades to:
- 29-41" Brown (10YR 5.5/2.5; 4/2m.) light clay loam, massive, porous (suggestion of weak subangular blocky in lower part), friable, slightly hard, calcareous, grades to:
- 41-62" Pale brown (10YR 6/3; 5/3m.) slightly stratified light clay loam, loam, and fine sandy loam (average loam), massive, very friable, soft, calcareous.

Site - 13 a

Owner: W. A. Squire

Profile Location: 1000' S and 100' W of NE corner of NE $\frac{1}{4}$ of Sec. 30;
T 24-S, R 39-W.

Irrigation: By well since 1951.

Soil Type: "Las Animas Clay Loam"

Description of Profile:

- | | |
|--------|---|
| 0-10" | Grayish brown (10YR 5/2; 3/2m.) light clay loam, weakly granular, friable, hard, calcareous, few worm castings in lower part, grades to: |
| 10-20" | Grayish brown (10YR 5/2; 3.5/2m.) clay loam similar to above except for the intermediate and mixed color, worm castings numerous, occasional fine gravel in lower part, grades to: |
| 20-38" | Light brownish gray (10YR 6/2; 4/2m.) sandy clay loam with few fine brown mottles of faint contrast, massive with few viscules, friable to firm, hard, calcareous, weak soft lime concretions and films in lower part, grades to: |
| 38-62" | Pale brown sand mottled with yellowish brown in upper 4". Water table at about 6'. |

Site - 13 b

Owner: Marvin Shatterly

Profile Location: 900' S and 200' E of NW corner of NW $\frac{1}{4}$ of Sec. 29;
T 24-S, R 39-W.

Irrigation: None

Soil Type: "Las Animas Clay Loam"

Description of Profile:

- 0-16" Grayish brown (10YR 4.5/1.5; 2/2m.) light clay loam, moderate medium granular, friable, slightly hard, weakly calcareous, worm castings numerous below 6" depth, grades to:
- 16-29" Grayish brown (10YR 5/2; 3/2m.) clay loam, moderate medium granular with some weak subangular blocky, firm, hard, calcareous, few worm castings, grades to:
- 29-47" Light brownish gray (10YR 6.5/1.5; 5/2m.) sandy clay loam, few fine brown and gray mottles of faint contrast, massive, firm, slightly hard, calcareous.
- 47-62" Pale brown sand mottled with yellowish brown in upper 6".

Sites in Stevens County

Site - 14 a

Owner: Parsons Bros.

Profile Location: 100' N and 100' E of SW corner of SW $\frac{1}{4}$ of Sec. 4; T 31-S,
R 37-W.

Irrigation: By well since 1940.

Soil Mapping Unit: Ulysses Silt Loam

Description of Profile:

- | | |
|--------|--|
| 0-6" | Light brownish gray (10YR 6/2, 4.5/2m.), calcareous, light clay loam, (29% clay) moderate medium granular, hard, boundary clear. |
| 6-14" | Pale brown (10YR 6/3, 4/3m.), calcareous loam or silt loam, moderate medium granular, worm castings, root holes, hard, boundary gradual. |
| 14-26" | Pale brown (10YR 6/3, 4/3m.), calcareous loam, or silt loam, worm and root holes, lime concretions and films, hard, boundary gradual. |
| 26-38" | Pale brown (10YR 6/3, 4/3m.), calcareous loam, moderate medium to fine granular, worm and root holes, lime concretions hard, boundary gradual. |
| 38-62" | Light yellowish brown (10YR 6/4, 5/4m.), calcareous, sandy clay loam, lime streaks, worm and root holes, slightly hard. |

Site - 14 b

Owner: Kenoyer

Profile Location: 100' S and 100' W of NE corner of NE $\frac{1}{4}$ of Sec. 8;
T 31-S, R 37-W.

Irrigation: None

Soil Mapping Unit: Ulysses Silt Loam

Description of Profile:

- 0-10" Grayish brown (10YR 5/2.5, 3/3m.), light clay loam, moderate medium to fine granular, (some subangular blocky?), few worm castings, hard, boundary clear.
- 10-20" Brown (10YR 5/3, 3/3m.), light clay loam, moderate medium to fine granular and moderate medium to fine subangular blocky, several worm castings, porous, hard, boundary gradual.
- 20-40" Light brownish gray (10YR 6/2, 4.5/2m.), calcareous light silty clay loam, moderate medium to fine granular and some moderate medium to fine subangular blocky, many worm castings, hard, 1% soft lime concretions, boundary gradual.
- 40-60" Very pale brown (10YR 7/3, 5/3m.), calcareous light silty clay loam, weak medium to fine granular, porous, few worm castings, slightly hard, streaks of free lime.

THE EFFECTS OF IRRIGATION ON THE CHEMICAL PROPERTIES
OF SOME NORTH CENTRAL AND SOUTHWESTERN KANSAS SOILS

by

ROBERT MORTON DIXON

B. S., Kansas State University
of Agriculture and Applied Science, 1959

AN ABSTRACT OF A THESIS

submitted in partial fulfillment of the

requirements for the degree

MASTER OF SCIENCE

Department of Agronomy

KANSAS STATE UNIVERSITY
OF AGRICULTURE AND APPLIED SCIENCE

1960

ABSTRACT

A study was made to determine the effects of irrigation on the chemical properties of the soils of two of the major irrigated sections of the state - North Central and Southwestern Kansas. Primary concern was given to changes in the soluble salt and alkali status of the irrigated soils. Fourteen soil sampling sites, 5 in North Central and 9 in Southwestern Kansas, were selected as representative of large acreages under irrigation. From each site an irrigated and non-irrigated or short-time irrigated comparison soil were sampled by horizon to near 5-foot depths. Well water samples were obtained and analyzed, while river water analyses were supplied by the Kansas State Board of Health.

The following chemical analyses were made: pH of irrigation water, saturated paste and the saturation extract; electrical conductivity of irrigation water and saturation extract; major water soluble cations and anions in irrigation water and saturation extract; ammonium acetate extractable cations of the soil; and gypsum and calcium carbonate equivalent of the soil. Water soluble and ammonium acetate extractable cations were determined directly by a flame photometer. Carbonate and bicarbonate were determined by titration with acid and chloride by titration with silver nitrate. Sulfate was determined conductrimetrically as calcium sulfate. The cation exchange capacity was determined by first leaching with sodium acetate, washing with alcohol, leaching with ammonium acetate to remove the adsorbed sodium, and then by analyzing directly for sodium by the flame photometer.

The following generalizations can be made from the results of the analyses: (1) all of the irrigation waters of this study would be classified as low in sodium hazard and medium to very high in salinity hazard according

to the classification system used by the U. S. Salinity Laboratory; (2) while there generally were some increases in exchangeable sodium percentage of the irrigated profiles, the levels were well below those considered hazardous; (3) a slight reduction to a slight increase in the salt content of the irrigated soils was associated with the use of waters having a medium salinity classification; (4) large increases in the salt content of the irrigated soils generally was associated with the use of waters having a high or a very high salinity classification. Three of the sites irrigated with such waters contained hazardous or near hazardous amounts of soluble salts.

Highly significant correlation coefficients were obtained for the relationship between sodium adsorption ratio of the saturation extract and the exchangeable sodium percentage for the horizons of both irrigated and non-irrigated profiles. Significant correlations also were obtained between the following chemical characteristics of irrigation waters and soils: (1) sodium adsorption ratio of irrigation waters and the mean exchangeable sodium percentage, both for the upper 2 feet and the entire profile; (2) per cent sodium of irrigation water and the mean per cent sodium of saturation extract for the entire profile; (3) total soluble cation content of irrigation waters and the mean total soluble cation content of the saturation extract for the entire profile.